MANAGEMENT EDITION

THE Petroleum Engineer

What's Ahead for Oil and Gas
Canadian Oil Eyes Further Markets
Review of Deep Drilling, 1954
Electronic Control of Refinery Pumps

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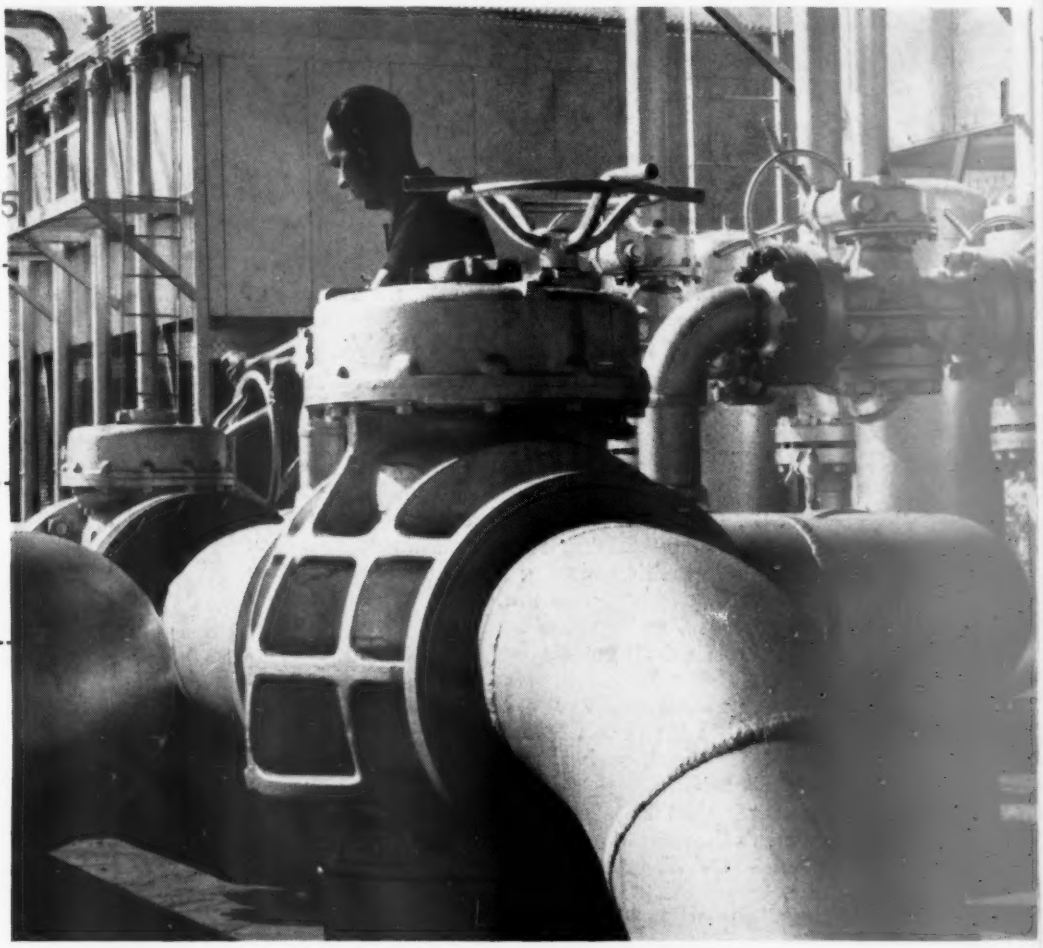

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JANUARY 1955

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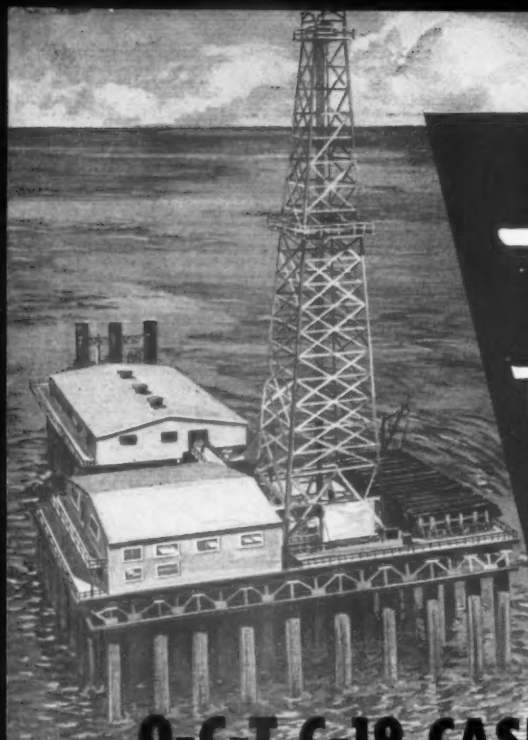

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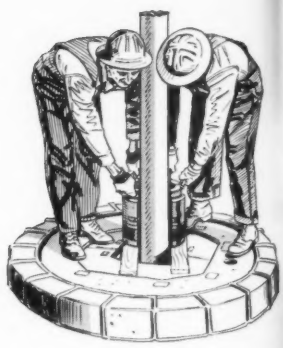

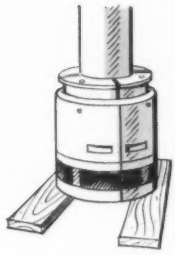

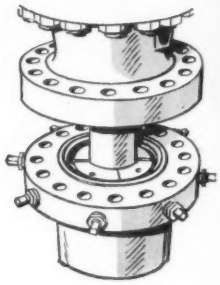

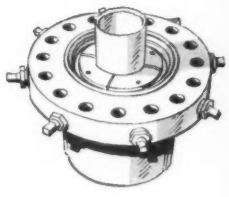

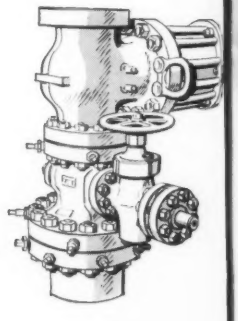

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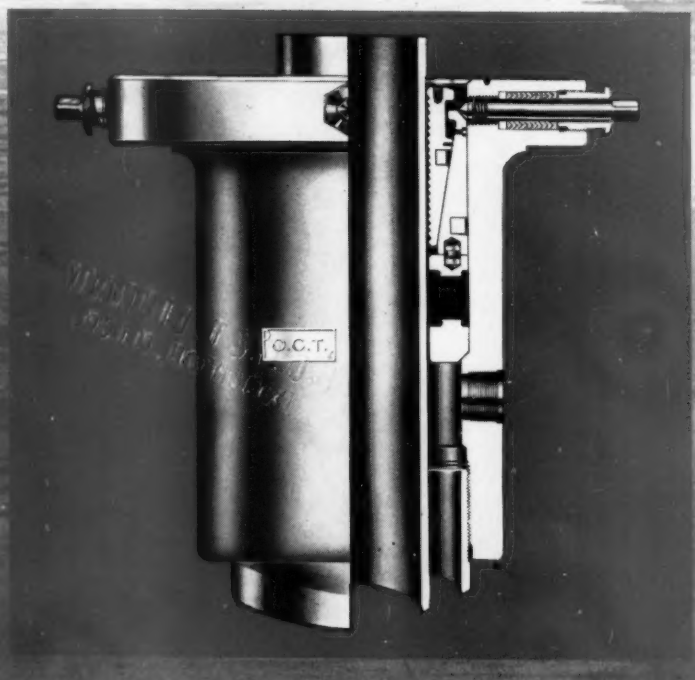

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LETTERS

Brooks Review Invaluable

The exceedingly able series of articles by Dr. B. T. Brooks reviewing developments in Petroleum and Petrochemical Processing which you published in your issues of January, February, March, and May, 1954, were a real contribution to all your busy readers. It is as exceptional to find such clear, logical, and well-written summaries of technical advance as it is valuable to have them today. I know whereof I speak because I am at work on a condensed one-volume edition of my six-volume history, "American Chemical Industry" and review articles of this sort are not only suggestive and stimulating to me, but they are excellent material to which to refer readers who require more details than I can give the book. Any man who wants to be brought up-to-date quickly and accurately in this fast-growing field would be grateful to this series of articles.

Williams Haynes.

161-163 Water Street
Stonington, Connecticut

Editor's Note:—This delineation of the far-reaching value of the Brooks series of four articles (Refining & Petrochemical Edition) written by the best known and most authoritative writer-historian of world industrial chemistry developments in this generation is so important that it is published here for the information of all those interested in this field. Other contributors characterize this series as the most concentrated and all-covering summation of important facts in the history of refining and petrochemical developments in the last half-century. It is gratifying to know that our best authorities for once at least seem to agree with the editor in his judgment that the Brooks series is the best assembly of articles by a single author published in 1954.

Iranian Pact Explained

The "Too Little To Too Much" paragraph on page C-3 of the October issue of *The Petroleum Engineer* wrongly presumes that Abadan refinery will be handed back to Anglo-Iranian Oil Company if the agreement now before the Iranian Majlis is ratified. The facts are that Anglo-Iranian is one of eight companies, five of them American, which will restart the nationalized Iranian oil industry with the approval of Iran. Anglo-Iranian will have a 40 per cent interest in the operation, the American concerns eight per cent each, and the remaining 20 per cent will be held by Royal Dutch Shell (14 per cent) and Compagnie Francaise des Petroles (6 per cent).

As regards Abadan's output, it was announced in a joint statement by the Iranian Government and representatives of the eight companies in Tehran on August 5, 1954, that starting from three months after the agreement comes into effect, a total of nearly 220,000,000 barrels of crude would be processed by Abadan refinery during the first three years of operation. Of this some 94,000,000 barrels (approximately 260,000 bbl a day) would be processed during the last of the three years. This is in contrast to the refinery's 1951 production of 500,000 barrels a day.

C. B. Towill

Purchasing Agent in U.S.A.
Anglo-Iranian Oil Co., Ltd.
London, England

Foreign Operations

We are a regular subscriber to your magazine *The Petroleum Engineer* and have read with much interest the "Oil Company Annual Report for 1953" published in your May 1954 issue. There are, however, some points which we do not understand and shall be grateful if you could enlighten us in respect of the following.

(1) Reference Page A-72
In respect of the figures shown under the various headings, the footnote thereto explains that the company's designated with an asterisk have foreign operations. We should like to know whether the figures shown include the rereturns from such foreign operations or not.

(2) Reference Page A-77
Whether the figures shown under the various headings in Table 2 also include figures from foreign operations or not.

Thanking you for your kind attention to our inquiry.

K. Nakamura.

Overseas Division
Ishihara Sangyo Kaisha, Ltd.
Tokyo, Japan

Editor's Note: The figures on A-72 include all incomes of the companies listed, both inside and outside the United States. In Table 2 on oil and gas operations, A-77, the figures include both domestic and foreign except where the footnote "in U. S. only" is indicated.

THE *Petroleum* Engineer — Management Edition

Exploration—Drilling—Producing • Refining—Petrochemicals—Gas Processing • Oil and Gas Pipelining

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Industry Armed for Battles Ahead

As the petroleum industry enters the year of 1955 it finds itself beset with certain problems. Problems are always present, but they do vary in their degree of gravity. The year ahead has several that are grave.

What are the most serious matters that confront the industry? We believe these: (1) Excessive production; (2) the possibility of the industry being taken over by the government, with the Supreme Court decision in the Phillips Case as the foot in the door, and (3) imports.

At present, capacity of wells to produce is variously estimated at 1½ to 2 million barrels in excess of demand. Imports have reached a figure that is causing a loud outcry from the independents. The Phillips decision, which has placed virtual control of the gas industry in the hands of the federal government, catastrophic in itself, could also lead to control of the entire oil and gas industry unless changed by congressional action.

These are serious problems unquestionably. But the bright spot that stands out in all this is what might be called an awareness and organizational strength in the industry, which gives one a feeling of confidence that about anything can be accomplished that needs to be.

Such has not always been the case. It isn't difficult to think back a few years to the Kerr Gas Bill, for example. How much effort was exerted to inform the public of the true significance of this legislation as is being done now in the Phillips Case? If the Kerr Bill had not been vetoed there would be no Phillips Case today.

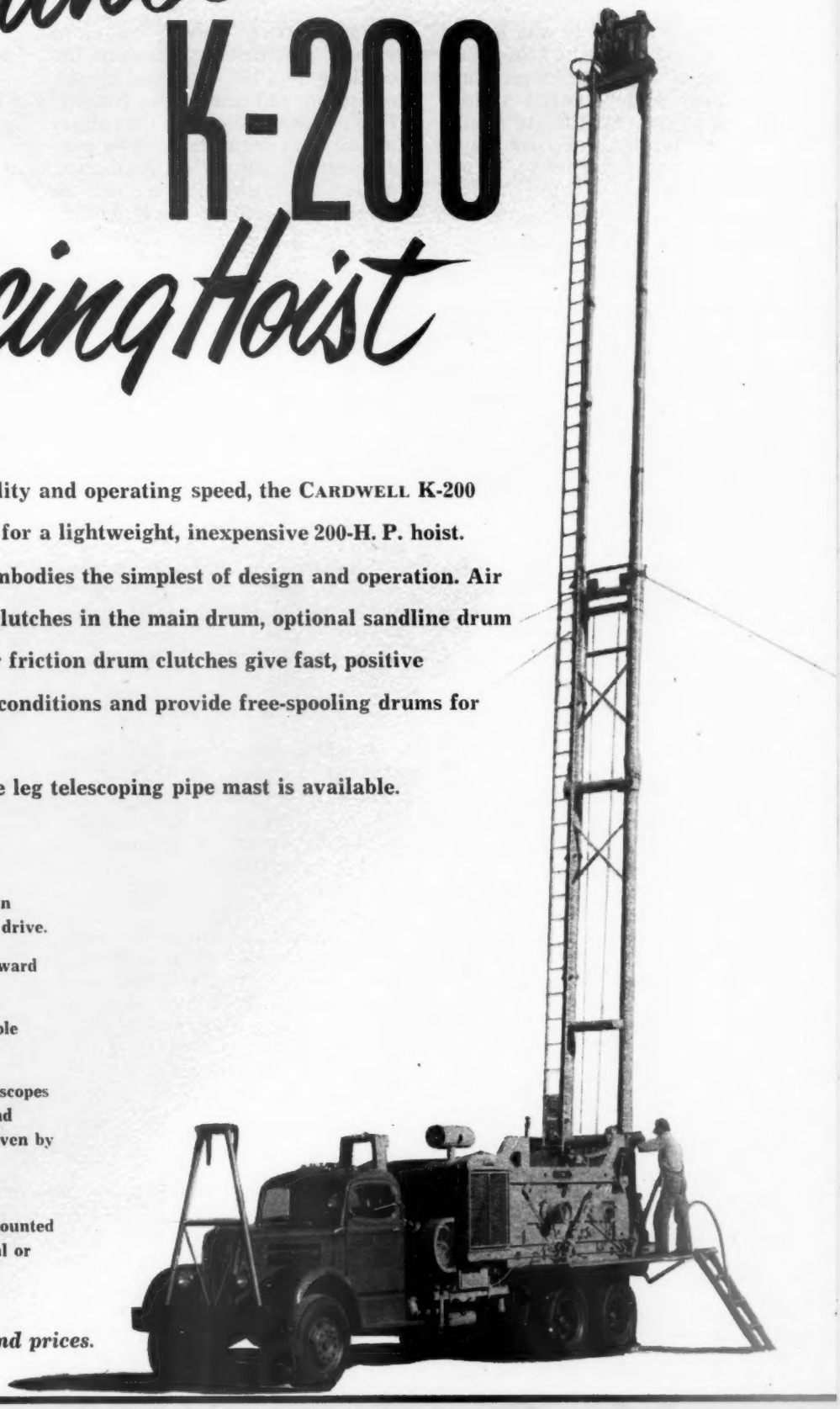
Think back considerably further, to another era of overproduction in the early 1930's when the East Texas field flooded the world market. Crude prices dropped to the distressing level of 10 cents a barrel. Now, with an overproduction capacity of 1½ to 2 million barrels a day, no one has been hurt by disastrously low prices and waste.

Imports? An important and controversial matter certainly. Importers feel they are not excessive and cite their reasons. On the other hand, independent producers have the means of impressively bringing their side of the story to the attention of the public. It is not difficult to believe that a solution will be found.

This ability of our industry to meet problems from within and from without has grown and developed from wide experience and sincere good will. It has been given strength and confidence by men of integrity who unselfishly sacrificed their personal inclinations for service.

Despite its many problems the petroleum industry meets 1955 confidently and determinedly. It will — as always — advance through the New Year successfully.—*Frank H. Love.*

CARDWELL Announces the New K-200 Servicing Hoist



Designed for utmost mobility and operating speed, the CARDWELL K-200 servicing hoist meets your needs for a lightweight, inexpensive 200-H. P. hoist.

The design of the K-200 embodies the simplest of design and operation. Air controls operate the air friction clutches in the main drum, optional sandline drum and rotary drive. CARDWELL air friction drum clutches give fast, positive engagement under all operating conditions and provide free-spooling drums for fast dropping of the block.

A 65-foot or 55-foot double leg telescoping pipe mast is available.

FEATURES

CARDWELL air friction clutches in main drum, optional sandline drum and rotary drive.

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Free-spooling drums, mounted on double row, self-aligning bearings.

65-foot or 55-foot double leg mast telescopes and folds over the hoist. Mast is raised and extended by line from winch which is driven by truck engine.

K-200 is available with GM 6031-C or Waukesha 145GKU engine, and can be mounted on a WC-2264 White, RF-195 International or 800-Ford truck.

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HIGHLIGHTS

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Digest of News and Comment

Another blow to oil and gas industry was delivered by FPC by announcing it would no longer honor escalator and "favored nation" clauses in gas certificate filings. Changing its rulings, effective May 1, restates controversial orders 174 and 174-A delivered to carry out Supreme Court's mandate in the Phillips case.

★ ★ ★

D'Arcy Exploration Company, Ltd., subsidiary of Anglo-Iranian, will increase its holding to 50 per cent interest in Triad Oil Company, Ltd. of Calgary, Canada. Result of option terms in an agreement in 1953, action will ultimately increase D'Arcy's investment in Triad to $19,500,000.

★ ★ ★

"Better driving—not less driving" is new theme of the oil industry under the direction of the American Petroleum Industries Committee. This is another attempt to encourage safe driving without frightening its customers off the highways, pointing up pride in careful driving—rather than fear of careless driving.

★ ★ ★

$108 Million deal is in the making by Sinclair Oil and Gas Company and American Republics Corporation. Under contract terms now being studied, American Republics would be dissolved, and holdings in Texas, Louisiana, and New Mexico would be operated by Sinclair.

★ ★ ★

First oil discovery has been made by Texaco Exploration Company on its high-priced 87,000-acre Pembina area tract. Well, tested at 6099-6112 ft, is 85 miles southwest of Edmonton, Alberta, flowed 22 bbl per hr of 40 gravity oil on a 3-hour test.

★ ★ ★

Shell Oil Company has received the first major contract in the United States for fueling Capital Airlines 60 four-engine turbo-prop planes. Turbo-prop, using kerosine for fuel, is now accepted as the next logical step in air transportation development. Contract will run four years.

"Spending money to save money" criteria may stabilize the economy in 1955 as related to new equipment and plant outlay budgets. Five per cent decrease in the nations industry has been predicted by government officials, although oil companies and their suppliers will be among continued "free spenders" in this phase. Tide Water Associated will hike to $127 million its expansion outlay for 1955; Jones & Laughlin Steel will spend $51 million, doubling last year's expenditures; Reed Roller Bit Company will spend 50 per cent more for new equipment. DuPont, Shell, and Jersey Standard will maintain last year's high budget for this category. Texaco is planning to spend over a billion dollars on its expansion program in next three years.

★ ★ ★

Government has signed contracts on nearly all its 27 synthetic rubber plants, with the majority going to major oil companies. Sale prices on the plants will be released late in January.

★ ★ ★

A million injury-free man-hours of work has been chalked up by Phillips Petroleum Company's production department. This achievement is infrequent in the industry's producing operations.

★ ★ ★

Oil stockpiles continue to dwindle as first cold weather is forcing heavy use of heating fuels. Increased demand on a nation-wide scale has also been noted in gasoline. Production for December is slightly above that of last year, resulting in more active refineries with a firmer overall price structure.

★ ★ ★

Taking advantage of currently lower domestic stocks, a 257,307 bbl per day allowable increase in January has been ordered by the Texas Railroad Commission. In an attempt to recapture a loss to foreign oil and production of other states, Texas raised its daily allowable flow to 3,216,123 bbl, nearing a record flow set in November, 1952. Oklahoma has also announced an allowable increase for January.

Nation's electricity output is nearing a production milestone—10 billion kilowatt-hours of power in a single week. This output rate is 65 per cent higher than 5 years ago, and is double available power supply just 8 years ago. Fuel-generated electric power has increased by 152 per cent in this period, as compared to 35 per cent rise in hydroelectric output.

★ ★ ★

Thirty top men of industry met recently with officials of the Office of Defense Mobilization to put into operation a standby force of men trained in government duty with important functions in an emergency. Such a backlog of personnel would help avert the confusion and delays which have developed in previous emergencies.

★ ★ ★

Price hike in North Dakota crude last month brings that state on a par with that paid in others; $2.90 per bbl will be paid for 40 gravity or more crude, with a 2-cent differential for each degree downward, by Stanolind Oil Purchasing Company. Amerada, controlling nearly 85 per cent of North Dakota production, voiced its approval.

★ ★ ★

Petroleum chemistry has been called upon to expedite further discovery of some 400,000,000,000 bbl of oil believed under the world's land areas. New chemical procedures relate oil to its source rock, and analyzation of soil samples might prove a direct method for locating oil in the future, according to Dr. J. M. Hunt, Carter Oil research chemist speaking before Southwest regional meeting of the American Chemical Society.

★ ★ ★

Idaho is making another attempt at becoming an oil-producing state. Rocky Mountain Oil Corporation has moved back over a well abandoned in the summer of 1954, in Bear Lake County, in extreme southeastern Idaho. Plans are to deepen to the Nugget formation around 5000 ft. Natural gas has been found for years and is being used in the potato-curing plants in that state.

Take it up with
Stearns-Roger

The petroleum industry is a hard task master! Advancing technology imposes increasingly complex and difficult problems ...and a driving search for answers that meet both physical and economic requirements.

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First Producers' Group United for the sole purpose of curbing foreign crude imports has been formed at Fort Worth, Texas. Those urging Congress to use immediately its legislative powers to reduce imported oil are the IPAA, TIRPO, North Texas Oil and Gas Association, Panhandle Producers and Royalty Owners Association, East Texas Oil Association, and West Central Texas Oil and Gas Association.

★ ★ ★

Gulf Oil Domestic Crude Purchases have been increased to a total of 170,000 bbl per day. Some 15,000 bbl trimmed from planned daily imports of 144,000 bbl, and made up through domestic production, is responsible for the increase. Gulf is the first to announce import cuts for the new year. The Texas Company also announced a decrease in imports.

★ ★ ★

Shale-Processing Plant of commercial size will be built soon by Union Oil Company of California. Location is to be near Rifle, Colorado. Size and design of the unique plant is now under study.

★ ★ ★

Sooner Independents Organize to form the Oklahoma Independent Petroleum Association. Action, termed "overdue by 20 years," seeks a larger cut of the market for Oklahoma oil, and to defend allowables for the thousands of independent operators.

★ ★ ★

Legislative Import Curbs get thumbs down by Colorado Governor Dan Thornton, speaking before the NOMADS, Houston. Fearing further governmental control in the oil industry, he favors voluntary restrictions of foreign crude imports by the big companies—before it is forced on them.

★ ★ ★

1954 Education Grants made by Jersey Standard and affiliates exceeded the million dollar mark with a December announcement giving $500,000. Latest contribution will benefit 138 privately-supported colleges and universities, as well as a portion for medical education.

★ ★ ★

First Company to Build Atomic Oil Lab is Standard Oil Development (Jersey Standard). Radiation laboratory is to be built in Linden, New Jersey, with goal of improving and transforming petroleum products through use of atomic energy. Several oil companies have used isotopes in research.

★ ★ ★

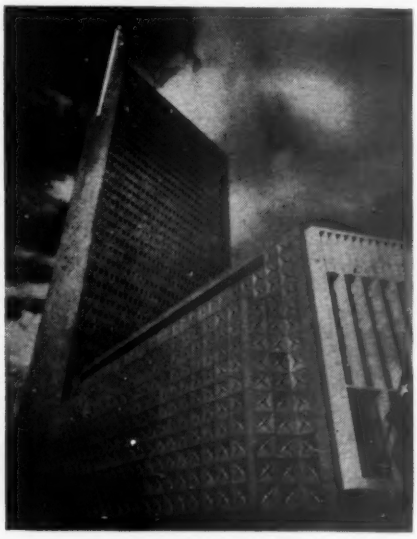
Oil Companies' Tax Write-Offs account for most of recent approvals by Office of Defense Mobilization. International Petroleum and Chemical Exchange received the largest, some $9,580,000 facilities. Phillips Petroleum received over $6,000,000 in quick amortization permits on a proposed refinery, natural gasoline plant, and oil storage. Standard Oil of Texas received permits on $4,000,000 to be spent for oil pipe line facilities.

★ ★ ★

Oklahoma's 8-Year-Old Oil Rules are being rewritten to conform with recent developments and practices within the state. Action will be taken January 12-14 by committee on revision and recodification of rules governing state's oil industry.

★ ★ ★

Pacific Coast Demand Increase is predicted by Marion E. Dice, Economics Department of General Petroleum. Petroleum demand will be 3.6 per cent over last year in the five Pacific Coast states, depending on a cold winter in 1955 and a lack of increase in natural gas imports.



Largest Bank Building, the Republic National in Dallas, Texas, has formally opened its doors to a building rising 40 stories, and having biggest west of Mississippi" title. Oil and Gas department is Republic's largest.

Sales of Oil Firms are much in the news. Monterey Oil Company has announced purchase of Fullerton Oil Company for a cash consideration of $50,000,000. Production acquired includes 5700 bbl per day of crude, 3800 bbl of natural gasoline and LP products, and 475,000 cu ft of dry gas daily.

Purchase of Kirby Petroleum Company holdings by Continental Oil Company is in the offing. Kirby's properties include 32 producing fields in seven states, as well as plants now in operation and under construction in Texas and Louisiana.

Arkansas Louisiana Gas Company (Cities Service controlled) is being sold to Mississippi River Fuel Corporation. This sale, involving nearly $25,000,000, will sever production, gathering and extraction facilities from Arkansas Louisiana operations. Company will retain its distribution facilities in Arkansas, Louisiana and Texas.

★ ★ ★

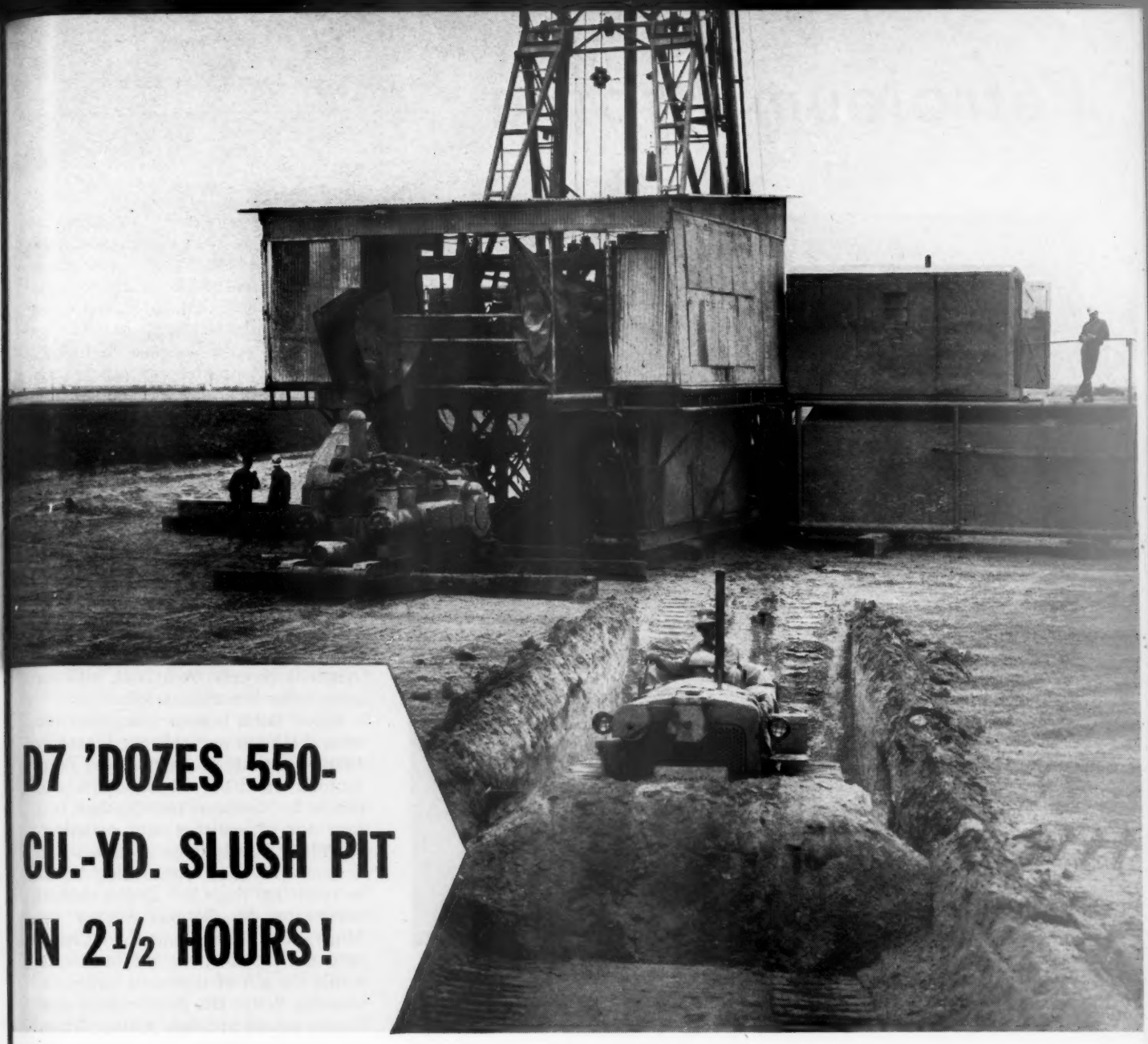
White House Level 'Task Force' suggestions to President Eisenhower for use in legislation will probably include: (1) a mild brake on imports of crude and residual fuel oil, (2) removal of the 50 per cent limit related to present tax depletion allowance of 27.5 per cent, and (3) removal of FPC controls on independent gas producers.

★ ★ ★

Present Gasoline and Lubricating Oil taxes are being eyed by the Bureau of Public Roads to help finance the $101 billion, 10-year highway program. Government's share, $24 billion, could be paid by continuation of the so-called "temporary" tax without additional appropriation or increase of federal debt limit. Suggestion was made by General Clay, chairman of President's advisory committee on the national highway program.

★ ★ ★

Largest Land Transfer in Texas' History has probably been effected by the creation of the TXL Oil Corporation. Assets of the Texas Pacific Land Trust amounting to $170,000,000 worth of oil, gas, and mineral rights on some million and a half acres of West Texas land in 30 counties, was passed to TXL. No cash was involved. Stockholders of the trust company will retain surface rights and receive some of the TXL common stock.



D7 'DOZES 550-CU.-YD. SLUSH PIT IN 2½ HOURS!

Just 2½ short hours after this picture was snapped, a 50′ x 50′ x 6′ slush pit was ready for action. The tough Cat* D7 Tractor that did the work, moved on to another job.

"It's always ready to go," comments owner Donald Andersen of Andersen Construction Co., Sterling, Colo. "We use our D7 for pit work and skidding rigs. We know where we stand with it."

Mr. Andersen has been using this tractor equipped with a No. 7S Bulldozer in the growing Denver-Julesburg Basin field, 20 miles northwest of Sterling.

This unit fights rising costs with the same tenacity that it attacks its work. From site preparation to cleaning up, you never run out of jobs for this big yellow work horse. It clears brush, levels drill sites, builds roads, digs and finally fills pits, moves rigs, digs gathering line trench, dikes storage tank areas and levels finished well sites.

Caterpillar equipment—all of it!—was built for hard-and-heavy use in rough country. Protected final drives and track rollers keep dust, mud and water out, lubricant in. And its sure-footed traction uses maximum engine power to do many jobs quickly and inexpensively.

Your Caterpillar Dealer can . . . and will . . . demonstrate his profit-building equipment on your job. Call him today!

Caterpillar Tractor Co., Peoria, Illinois, U. S. A.

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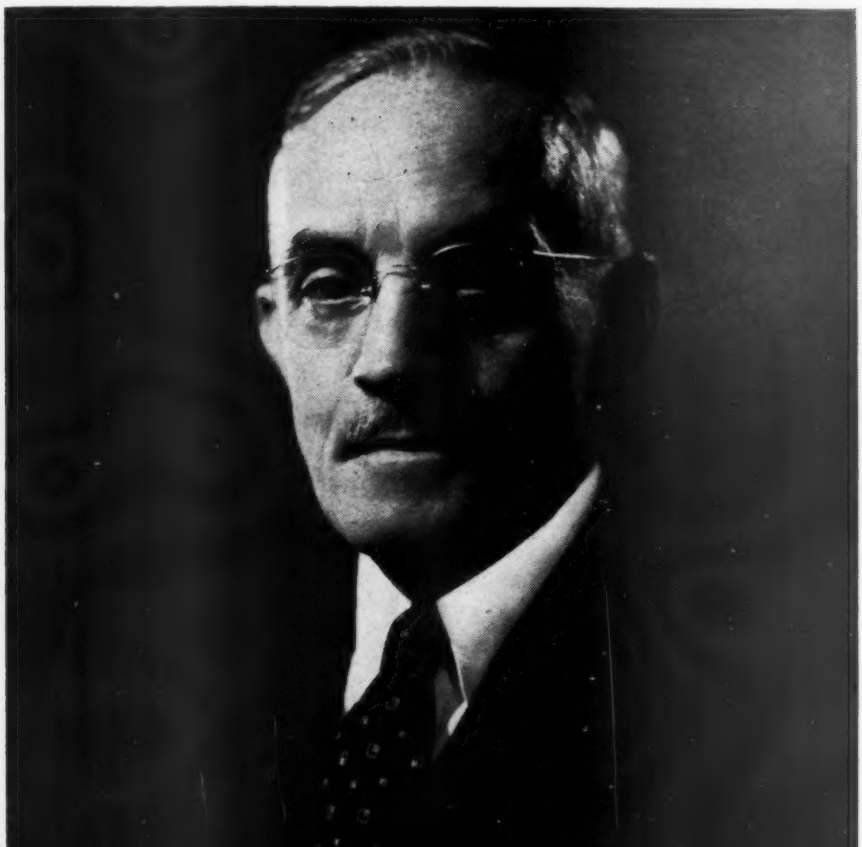
**NAME THE DATE . . .
YOUR DEALER
WILL DEMONSTRATE**

Petroleum Profile



GUSTAV EGLOFF

Scientist

INTERWOVEN inextricably in the fabric of the petroleum industry in its phenomenal achievements during the last half century is the name, and work of "Gus" Egloff, known wherever petroleum technology and science are known. Hundreds (650) of technical articles, interspersed with numerous informative articles that may well be called semi-popular in nature, along with 10 books and some 300 patents on petroleum and chemical technology, attest to his prolific work and writing, covering these fields to an amazing extent.

Gustav Egloff has been in the forefront of the developments in petroleum refining, especially in thermal and catalytic cracking. Becoming affiliated with the Dubbs process and Universal Oil Products Company about the time of World War I, he took a very active and leading part in the development of this, one of the outstanding processes for conversion of heavy hydrocarbons to motor fuel, including process and patent development and also in the court actions designed to establish priority for certain discoveries in thermal cracking. Along this line legend has it that he holds the world's record for length of court time devoted to the answering of a single question, said to have required some three weeks' testimony—and then he did not complete the definition of an emulsion, to his satisfaction.

In collaboration with the late great V. N. Ipatieff, whom Egloff was largely instrumental in bringing to America in the 1930's, a new phase of hydrocarbon chemistry was ushered in. The process for polymerization of waste refinery gases, propylene, butene, pentenes, etc., was one of the first accomplishments, a process in well-nigh universal use in the industry now, pointing the way to later methods. Alkylation of isoparaffins, the reactivity of which had not been known practically before, paved the way for 100-octane avgas, and gave a new concept to petroleum chemistry that has dictated and governed research since that time.

No satisfactory resume of Egloff's various accomplishments can be presented, for lack of space; the story requires a small volume. Of Swiss parentage, he received a bachelor's degree from Cornell University, the master's and doctor's from Columbia, working especially on chemical engineering, organic and physical chemistry, emulsions, hydrocarbon reactions, and other fields. In addition to Dr. Ipatieff he brought Dr. Hans Tropsch to America for research work. Dr. Tropsch is well known as co-developer of the Fischer-Tropsch hydrocarbon and chemical synthesis process from coal, and for many other important studies.

Egloff holds honorary degrees from several schools and colleges, including Illinois Institute of Technology, Polytechnic Institute of Brooklyn and others; has honorary memberships in a long list of societies and technical-scientific organizations at home and abroad. His latest outstanding honor is receiving the Carl Engler Medal Award by the German Society for Mineral-Oil Science and Coal Chemistry last October, the highest award within the gift of that most important scientific body. His memberships and honors extend to South Africa, Japan, Brazil, Scotland, France. He is placed on innumerable boards and committees, military and scientific, on API research projects, British Institute of Petroleum's editorial advisory board, Inter-American Engineering Co-operation Committee of the American Institute of Chemical Engineers, and additional honors long enough to require several pages merely to list them.

In the fall of 1954 he visited mainly Germany and England, lecturing and giving papers in a number of places.

Egloff may be referred to properly as indefatigable; also, he is never at loss for words. In 1945, when a newspaper reporter told him via phone of the first atomic bomb explosion, and said that no further gasoline for power was needed, Egloff took issue with him, maintaining what we now know to be true, that petroleum products are still indispensable to our civilization.

The brilliant scientist is one of our great Americans.

WHAT'S AHEAD FOR OIL AND GAS IN 1955?

SIM CREWS, ARCH L. FOSTER, and DEAN HALE

- *More wells, greater footage to be drilled*
- *Competition forcing product improvement*
- *Consumer demand and FPC regulation factors in pipelining*

THIS year, 1955, should be a good one for the drilling and producing industry. Naturally any prediction formulated in this troubled time of international tension, atomic bombs, hydrogen bombs, and the myriad of other death-dealing weapons devised by modern man must be predicated upon a continuation of the existing uneasy peace. This situation not changing, however, prospects appear favorable.

Generally we can presume that, with regard to drilling, more wells and more footage will be drilled in 1955 than in any previous year. That this may be accomplished with less labor and fewer rigs is possible and will be discussed later.

Completions will improve—secondary recovery operations will be more effective—lifting costs will even receive more critical attention on an "if we can't cut 'em at least let's hold 'em" basis—and, nationally, gross production may increase. For a more detailed appraisal, let's first consider the general economic aspects of 1955.

Allyn P. Evans, president of Lionel D. Edie and Company, New York, while addressing the last National API, sounded an optimistic note that is characteristically repeated by other competent observers. Basing his analysis on a review of the entire economy, Mr. Evans predicted a growth of 4 per cent in the national economy in 1955.

John Boatwright, Standard of Indiana, foresees an increased demand for petroleum and products of the order of 4.3 per cent. Translated into terms of production this means 262,000 bbl per day more crude will be required in 1955.

Dun and Bradstreet, in a recent survey of more than 1300 business executives found that 56 per cent expect higher sales, 43 per cent larger net profit after taxes, 14 per cent larger labor forces, and only 7 per cent feel their staffs will be reduced.

In summation then, competent observers feel the general economic tenor of the country will improve, will possibly be better even than record smashing 1953. How then will go drilling, how producing, how exploration?

Drilling—Footage Up, Rigs Down

This prediction, as voiced by A. W. Thompson, president of A. W. Thompson, Inc., and vice president, API, Division of Production, may not be as paradoxical as first it seems. Specifically Mr. Thompson expects that the drilling industry will record a 10 million foot gain in 1955 as it did in 1954. He believes this can be accomplished with 50 to 100 fewer rigs than used in 1954 or 250 to 300 less than were used in 1953. This prediction assigns the task of drilling in 1955 then to probably 2400 rotary drilling rigs and anticipates 217 million feet of hole.

To accomplish these results, the overall employment of the rigs must remain at a high efficiency level. Lost motion in moving must be eliminated. Surface activity of the drilling operation must be well planned and executed. A recent series of articles on methods improvement published in *The Petroleum Engineer* highlighted this requirement with an analysis of time lost while changing crews. It is estimated that the loss of only five rig minutes a tour will amount to almost four rig days a year, or, to be more specific, losing five rig minutes a tour wastes 1.04 per cent of the rig's working day. How much rig time is lost by the old custom of not pulling a bit until there is just time to set it on the bank before the relief arrives is anybody's guess. It must be considerable, however.

The rest of the slack in drilling efficiently must be taken up in down hole techniques. Already experiments with 75,000-lb bit weights are being carried out. Strict application of hydraulic techniques will continue to gain adherents, as it must in 1955. We should see more and more contractors thinking in terms of 200 to 280 ft per min annular return mud velocity and nozzle velocity up to 250 ft per second or higher for jet drilling. In the realm of the fringe drilling operations, the extremely hard formations of those in areas with excessively bad crooked hole conditions, expect further applications of diamond bits, the sintered carbide insert bits frequently called "chert bits," rotary percussion devices, and larger, longer, and heavier drill collar strings yielding bit weights up to a possible 10,000 lb per inch of hole diameter.

Expect, too, to see continued improvements in mud control with permissive attendant decreases in drill collar clearance where such is applicable and necessary.

Expect, in short, to see the drilling industry move forward in its continuing effort to provide more hole, and better hole, for less money.

Production—More New Oil —More Old Oil

Daily average U.S. crude production should increase in 1955 by some-

thing over 4 per cent if normal growth continues and we experience an average winter. Estimating 1954 daily average production at 6,320,000 bbl it is apparent that, imports continuing to enjoy their present relation to demand, we shall produce something over 250,000 bbl per day more than we did in 1954.

A portion of this extra crude will undoubtedly come from new discoveries. In 1954, wildcatting had an indicated success rate of slightly over 17 per cent with something over 1800 successful completions.

Additional reserves and added production capacity will stem from further correct application of fracturing techniques. It is now considered that, where not abused or mis-applied, these techniques are resulting in large, sustained, and *stabilized* increases in potential, both in oil and gas zones.

Development of logging potential, more accurate perforating technique, better cementing, and possibly the continued expansion of diesel oil cement squeezes will aid their reservoir completions and promote their commercial exploration.

In the same vein, the permanent completion where properly used will lower completion and operating costs to the point where presently submarginal prospects will become commercial thus adding their bit to the production potential. This result has been evident in 1954 and may well be expected to continue in 1955.

Expect secondary recovery operations to play an important role in 1955 production also. Many large floods are coming into their peaks, others will be implemented and show some response within the year.

Continuation of experiment with high pressure gas injection, cycling operations, the use of detergents and solvents—all will be important in the year's picture. And the underground combustion process will continue to be investigated and evaluated. No commercial application is expected this year, however, since inception of the operation is still too young.

Exploration—More Due

Geophysical exploration, principally seismic, should continue at a high level. It appears that geological core holes, particularly those in the 4¾- to 6¼-in. range and in the 2500 to 4000 ft depth bracket may gain increasing favor. The determination of local velocity values for use in seismic interpretation is one of the major profits from these holes. This information, coupled with stratigraphic and structural determinations, render them particularly valuable exploration tools.

Further application of gravity, magnetic, airborne magnetic, and probably direct determination exploration tools is certain. With regard to the latter, continued investigation of radio activity determinations, soil bacteria examination, ground water analysis, and other phenomena continues to show possible promise of becoming a valuable aid in locating accumulations of oil or gas.

Year of Promise and Problems

There is little doubt that 1955 can be a great year for the oil industry. As mentioned earlier, the possibility of war must be considered and its coming would doubtlessly alter the industry's course drastically. Our leaders have publically proclaimed, however, their belief that the cold war will not become a shooting war and, accepting this, we can expect the oil business to prosper.

Three clouds are present though, on the domestic horizon, and no review of the year can ignore their lengthening shadows. Listed, but not necessarily in order of their importance, they are imports, depletion, and FPC control of gas producers. The disposition of these problems will probably depend almost solely on politics with the possible exception of the import situation, where industry self-regulation may yet prevail. All of them have a tremendously important bearing on the ultimate course of the industry this year and favorable solutions are imperative to its continued well being.

REFINING and PETROCHEMICALS . . .

WITH the "Fool's Heaven" of war-generated products demand behind us, with the advent of pseudo-peacetime needs of the world moving in to set again into operation the inexorable law of supply and demand, the refiner executive finds it more necessary than ever that he and his staff read the signs of the times correctly in order to stay on the black side of the ledger. The compositions of the same *old* crudes are the same as formerly they were; *new* crudes vary only in degree.

The financial well-being of the refiner tomorrow, as of today, is based on his decisions on such questions as: How high octane number motor and/ or aviation fuels shall we make? How high yield percentages of gasolines is the economic optimum, for us? What will be the situation two years after this unit or this plant is completed? Will we then be overbuilt, facing a falling demand, slumping prices, changing specifications, a retrograde economy?

Just for purposes of comparison, look at the brief table printed herewith. For this purpose Bureau of Mines production figures for crude and the various primary products for the years 1933 and 1953 have been taken, and the yields of each of those five products are shown, both in barrels total, and in percentages of the crude processed for the year.

Product	1933 1000s bbl	1933 Per cent of crude	1953[1] 1000s bbl	1953[1] Per cent of crude
Crude	861,254	100.00[2]	2,359,998	100.00
Gasoline	408,284	47.50	1,259,040	53.50
Kerosine	48,921	5.78	129,751	5.50
Distillate fuel oil	79,060	9.20	532,221	22.60
Residual fuel oil*	236,395	27.40	449,979*	19.00*
Lubricating oils	23,805	2.78	52,545	2.25
*Imports	136,209			
Exports	26,208			
Net imports	110,001			
Net domestic resid. F.O.			339,978	14.4

[1] Preliminary figures. [2] Slide rule-calculated percentages.

"Middle of Barrel" Most Important

Even cursory perusal of these figures proves very conclusively that of all the products listed, which list includes all the primary products made during the last 30 years, only two, distillate fuel oil and residual fuel oil, have changed appreciably. Look at gasoline; in 1933, the quantity was 408,000 bbl; but the percentage was 47.50, based on crude runs to stills.

In 1953 the *quantity* was three times as much, with the percentage on the crude increasing to 53.5, nearly 7 per cent. In 1933 distillate fuel oil used up only 9.2 per cent of the crude; in 1953 this climbed to 22.6, or 2½ times as high, percentagewise. Residual fuel oil 20 years ago took 27.4 per cent of the crude; in 1953 this fell to 19.0 per cent, *total*. Residual fuel imports in '53 amounted to 136 million bbl, with only 26 million bbl exported, for a net of 110 million bbl used in this country not derived from our operations. This shows a net of 340 million bbl made in the U.S., or only 14.4 per cent of the crude, about half the 1933 figure.

Adding to this the all-important principle of the refining industry, that the battle for the last third of a century has been for the "Middle of the Barrel," the big decision apparently must be as to just how this barrel-middle is to be split *and* refined.

But the equation is complicated by the introduction of another, financially important variable, that of petrochemicals, their monetary value, and the best utilization of the formerly "waste" products of the refinery, the gasoline plant. As of the time this goes to press, catalytic reforming units are in operation widely in this country and abroad. Catalytic cracking processes handle

more than half the cracking capacities of the industry.

The most important phase of all this field is the impact of catalytic cracking, of catalytic reforming on the whole refining panorama. The *number* of by-products is legion and the impact, current and actual, and future and prospective, is incalculable.

It has been estimated that if 5 per cent of the total material in the crude oil and gas production of these two industries is utilized eventually for petrochemical production the price return for these products will equal or surpass that from all the "fundamental" products made.

Octane Ratings Climb High

For gasoline and motor fuels, present developments are keeping step with developments in automotive engines. First, octane ratings of both regular and of premium fuels have "gone over the top," are still rising, not so much to meet engine demands as to induce sales in the tension-heightening "fight for gallonage." The real saving to the industry is to avoid production of "wasted" octane numbers and to put the advantage and the technical improvement into lowered fuel costs and improved engine economy.

Whatever the correct answer to all this, the fact remains that the octane rating has only one direction to go—upward. That contingency is in the nature of things. "Boss" Kettering, a few years ago, pointed out the obvious, that no matter what the diesel cycle, 16-to-1 compression ratio, can do, we can do and do better with the Otto—gasoline engine—cycle, operating on carburetor-type fuels. Already a 12-to-1 ratio engine has been operated at unheard of efficiencies, power-output-per-pound-of-gasoline values.

Gasoline Additives Stealing Show

Octane numbers will go upward at a rate that will be dictated not by the needs of the customer, or even of the engine primarily, but by reason of two phases of competition—that of the engine manufacturer selling power and that undefinable "performance" capacity; and the refiner, selling the same properties and propagandizing for sales advantage.

Otherwise, the trend is strongly toward the situation where, as one report said earlier in 1954: "Some gasolines contain everything but the kitchen sink." In these ingredients are included anti-rust compound, anti-stalling agent, gum inhibitor, upper-cylinder lubricant, anti-oxidant, pre-ignition depressant, de-icing agent, etc, ad nauseam. West Coast gasolines, now 94-95 octane number, will be boosted to 96-97 soon, it is reported.

The quantity of jet fuels required is determined almost solely by the military demand, in the near future. It is noted that, whereas in 1952 no jet fuel was being made, the quantity reported in 1952 is nearly 21,000,000 bbl, or one-fourth of the amount of avgas made for reciprocating engines, a total of 80,350,000 bbl. Uncertainty as to the specifications of jet fuels may or may not retard progress.

Supply of automotive lubricants has outstripped demand by about 25 per cent, in 1954, says Keyser (API, Nov. 1954) due in good measure to new types of lubricants. Reduction of engine crankcase capacity and less frequent oil changes have contributed to this. Multipurpose greases, and multigrade engine oils have helped reduce the demand. The trend inevitably is toward more expensive lubricants for the highest grade services and the most severe operating conditions; it is quite possible that the gross income from these higher grades may be equal to that from the older products.

In this regard the matter of synthetic products, lubricants, etc., offers some prospects for increased output for special purposes. The ultra-ultra lubricants brought out a few years ago are still with us, although having only slight effect on markets or trends. The tendency toward multi-grade oils (SAE grades) is calling for some synthetic components, or what may be called semi-synthetic products, materials made via catalytic processes. The trend toward synthetic components and/or to catalytic treatment to effect molecular and thus property changes is inevitable and "snowballing."

Shale Oil Potentially Important

Shale oil developments, while offering no appreciable impact on the production of the economy of the industry, is "looking up" so far as additional attention by the industry is concerned. The Bureau of Mines operations at Rifle and Laramie are being curtailed. Union Oil Company, with a company-designed retort is planning to build a unit near the Rifle center of operations, to carry on private research.

Atomic energy competition with petroleum and other 'natural' fuels is not a hazardous prospect, say oil leaders; will not displace oil as energy source in the "foreseeable future" (Follis, Standard of California). Atomic and oil sources will compete only in stationary power generation, that now calls for only 3 per cent of our oil production. By 1975 the atomic phase may supply 15 per cent of this power, but the total power output will have doubled that of 1955. Currently, investment cost for electric power generation is $120 to $150 per kilowatt; the first atomic reactor for this purpose will cost $600 per kilowatt, that later may be reduced to $200. Standard Oil Development Company is building a company-financed radiation research laboratory at Linden, New Jersey.

Petrochemicals

Petrochemicals will grow still "by leaps and bounds," with probably a slow-down in the next few years. In mid-'54 Ayres (C&EN, July 19, p. 2876) listed 13 points in his summary of prospects for organic chemicals raw materials. Oil shale will be important as byproduct source; present trend away from vegetable sources will continue. Special coal hydrogenation methods will increase amounts of coal-derived chemicals. LPG will be available as raw material until at least 1970. Chemicals from dry natural gas will decrease, not increase. Also, coal hydrogenation will not supply much LPG as aliphatics source. Conversion of coal via Fischer-Tropsch will supply olefins, ethylene, propylene, etc., but motor fuels by that process will be minor in quantity. Stanolind has bought into the Carthage Hydrocol setup, but apparently for chemicals production rather than motor fuels.

Press announcement is that a combination oil-rubber company (Goodrich-Gulf), has reproduced the "original" rubber molecule obtained over the years from tree sap alone. Costs are said to be, now, somewhat higher than for the so-called GR-S rubber, now about 23¢ per lb, from butadiene and styrene, and the new rubber uses "different materials" for its synthesis.

GR-S rubber will remain best for certain purposes, such as treads in tires. Probably also the greatest single raw material or intermedate for chemical synthesis is ethylene, which will be, and largely is, derived from refinery still gases, from cracking ethane, propane, butane from refinery gases or natural gas. It is estimated that 5 billion lb of ethylene will be needed to meet demands by 1962, by extrapolation this demand will be nearer 6 billion lb by 1970. (Ayres, and Kuhn-Hutcheson).

Closing: The demand for motor fuels involves two factors: properties and quantities. Demand for distillate fuels, diesel and household heating fuels will climb rapidly, to start "levelling off" in the 1960's, possibly. Residual fuels will drop correspondingly, though more slowly, since much residual fuel as such is and will be imported to meet industrial heating, railroad, and marine demands. Lubricant production will rise probably as total crude demand grows; will demand more improved *quality* than *quantity*. Petrochemicals

XUM

will expand phenomenally in volume and in total financial return, but will take up only minor proportions of the total petroleum-natural gas produced at any given time.

PIPELINING . . .

FROM all indications, the year 1955 will be another good one for the pipe line industry as a whole. Whether or not it will be a "great" year depends on two very important factors: 1. the continuing growth of our national economy and subsequent increase in consumer demands for petroleum products, and 2. how the crisis invoked by the FPC regulation question will be resolved.

Other "X" factors will have some effect—such as the import question, expansion needed to meet national defense requirements, discovery of new reserves and new production.

But none of these later factors will be as stimulating or deterring to growth of the pipe line industry as the economic and FPC questions.

The Economy. The outlook here is good. Predictions from many sources indicate that a minimum 4 per cent growth can be expected for 1955. Dun and Bradstreet, surveying some 1300 business executives, found 56 per cent expect sales increases, only 7 per cent pessimistic about the future. Government and business eeconomic advisers are in agreement that all forms of business endeavor will remain at high levels and in most enterprises there will be a great deal of expansion.

Regulation. Relief from FPC control for independent producers is a problem of national concern. But it could also be a political football in the next two years, kicked around without any decision or outcome. Referee will be Congress, whose decisions may well determine the future growth of the natural gas industry, and to a large extent, all activities of the entire petroleum industry. Stringent controls on gas producers could also impinge on crude oil production, hamper activities of conservation bodies, and bring an abrupt decline to normal industry expansion and development.

The effect on gas pipe line construction activity could be quite pronounced. Without necessary gas reserves behind applications—and producers will be reluctant to make any commitments in face of regulation—there will be fewer large diameter, long distance interstate lines built. Subsequently, there would be a decline in lateral and utility line construction, which has no justification for existence without gas to supply customers.

The Gas Industry. Despite the long shadow of Federal Control and Regulation that looms threateningly on the horizon, the gas industry is quite optimistic. American Gas Association president F. M. Banks, in a year-end statement, foresees a year in which the industry will spend another $1 billion for new construction. New customers for natural gas are being added at a rate of 800,000 per year and should continue at this or a higher rate for 1955 and 1956. The demand for natural gas is great—it now provides 25 per cent of U. S. energy needs—and waiting lists for service in many areas are very long lists.

Major gas pipe line projects proposed, authorized, or under construction at the beginning of the year total some 13,736 miles—to which can also be added an estimated 15,000 miles of lateral, utility, gathering and underground storage service lines that will be built. Compared with figures of a year ago (for 1954) this is only 1400 miles less. Several major pipe line authorizations have been made and many of the proposed projects most likely will be authorized. The FPC question has undoubtedly slowed plans for new lines and expansion programs, with the planners adopting a "wait and see" attitude.

Continued activity is seen for development of underground gas storage with possibly $40 million planned for 1955 expenditures. Another strong point in the gas picture is the expansion of reserves. Supplies continue to be found at a rate much above production. Again, utilization of this potential will be largely affected by what happens in regard to federal controls.

In the coming four years, says the AGA, some $4 billion will be spent on expansion in the gas industry. In that period, requirements for steel pipe will total 4.6 million tons, of which 2.9 million tons will be for pipe 16-in. diameter and larger. Another 134,000 tons of steel will be needed in other forms, and over 500,000 tons of cast iron will be required.

Oil Pipe Lines. If there were such an animal, 1955 could be picked as a "normal year" for crude and products pipe line construction. Lines planned, proposed, or to be completed in the coming 12 months add up to approximately 9774 miles, based on information thus far available. Broken down, this includes 3765 miles of crude lines and 4809 of product lines, with another 1200 miles of gathering lines needed to tie-in new production, which is expected to be ahead of 1954 production gains.

Some of the projects on the 1955 list are uncertain, and if eliminated, a more realistic figure would be a total 7904 miles. This figure compares well with average new mileage added during the past few years, and 1954 construction.

Development of new crude lines has reached an apparent point of stability, with construction around the 3000 to 3500 miles per year mark. Products pipe lines, however, should witness much greater activity. Several important projects as yet officially unannounced are expected to develop during the coming year.

The Year Behind. Although somewhat short of expectations, major pipe line construction in 1954 remained at a good level, with some 14,100 miles added to the nation's network. Crude and products lines accounted for approximately 7360 miles, while gas pipe line activity was down to 6786 miles of major lines. Total gas pipe line mileage for the year was about 17,500 miles, if the additional 10,700 miles of utility, lateral, and service lines are also counted in, and the grand total for all lines added in 1954 was nearly 25,000 miles, making the accumulated network read just a bit short of 650,000 miles.

Total mileage added would no doubt have been much higher had several major projects—crude, products and gas—commenced construction. A boost to crude line construction was the building of two major outlets from the Rocky Mountain region. Several large products carriers were completed, but 1954 wasn't the "banner" year predicted by some sources for construction of product lines.

OPERATIONAL TRENDS. The days of small and, often, multiple lines, closely spaced stations, and manual operations are gone. Even the pipe line systems whose plants are two decades old are turning to modern techniques and "revamping" to make operations more economical. Most new lines built today make great use of the latest control and instrumentation equipment. Lines are sized to meet anticipated capacities—sometimes 10 years ahead—and every possible factor that may affect future operations is considered and planned into the new lines.

Advancements of recent times such as bigger and more efficient prime movers, bigger and more efficient pumps and compressors, remote controls, microwave and two-way radio, stronger steel for line pipe, functional buildings, "packaged" components, and a host of other innovations will continue to grow in importance. More and more applied engineering thinking to pipelining is contributing to the attainment of the three "E's": *Economy, Efficiency,* and *Ease of operation.*

* * *

A. Capital investment is running much higher than revenue from oil and gas properties.

B. To profit from huge investment and to free capital for further development of petroleum, new markets must be found.

C. Canadian oil must compete with foreign oil at the end of pipe lines running East and West in order to extend markets.

Canadian Oil Eyes Further Markets

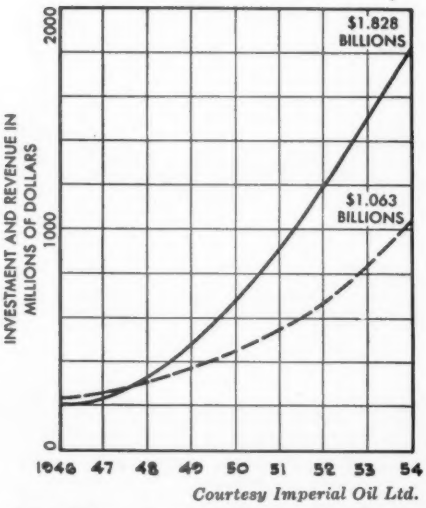
H. G. Cochrane

CANADA'S thirst for oil has doubled over the past seven years, mainly due to increased registration of motor vehicles, to the growth of farm tractors and other motor driven vehicles in use, all of which have almost doubled during this period; also to stepped-up installations of domestic oil burners, which have more than doubled, and to rail freight haul on Canada's railways, which is being rapidly dieselized.

But Canada's crude production is rapidly catching up. Domestic crude production, at 10 per cent of national consumption 7 years ago, has increased more than seven-fold over the same period. It is now supplying half the nation's needs and could supply three quarters of consumption if transportation facilities were available. Canadian natural gas, too, will within a couple of years be widely used for heating, cooking and industries in Quebec, Ontario, and the prairie provinces, probably in Minnesota and possibly in parts of the Pacific Coast states as well. This will indirectly help many Canadian oil producers by making a market for their gas, though gas is in some measure competitive to oil.

Gap Between Investment and Revenue

There are some three quarters of a million square miles of potential oil-producing territory within a triangle with its base the International boundary from Fernie, B.C., to Winnipeg, Manitoba, and its apex at Aklavik, where the Mackenzie River joins the Arctic. Over this area only one well is drilled for every 178 square miles, thus the area is as yet hardly scratched. Little wonder, then, that Premier Manning of Alberta stated with confidence last spring that "maximum exploration and development is assured for some years to come."



Courtesy Imperial Oil Ltd.

Cumulative expenditures and revenue Western Canada's oil industry 1946-1954. Broken line represents revenue.

Since the Leduc discovery in 1947, the petroleum industry in the three Canadian prairie provinces has established proved reserves of some 2.4 billion barrels of oil and 15 trillion cubic feet of natural gas. To prove up these resources, worth more than $3 billion in the ground, or some $7 billion at wellhead, the industry has over the past 8 years invested a total of nearly $2 billion for exploration and partial development. Revenues from the sale of petroleum products over the same period have totalled slightly over a billion dollars.

But to realize anything on this huge investment, to make profits, and to free capital for further development and exploration, markets must be increased. The gap between annual investment and annual revenue is still widening, and some way must be found to close it. If it can't be done by increasing revenue faster then investment must ultimately slow down.

EXCLUSIVE

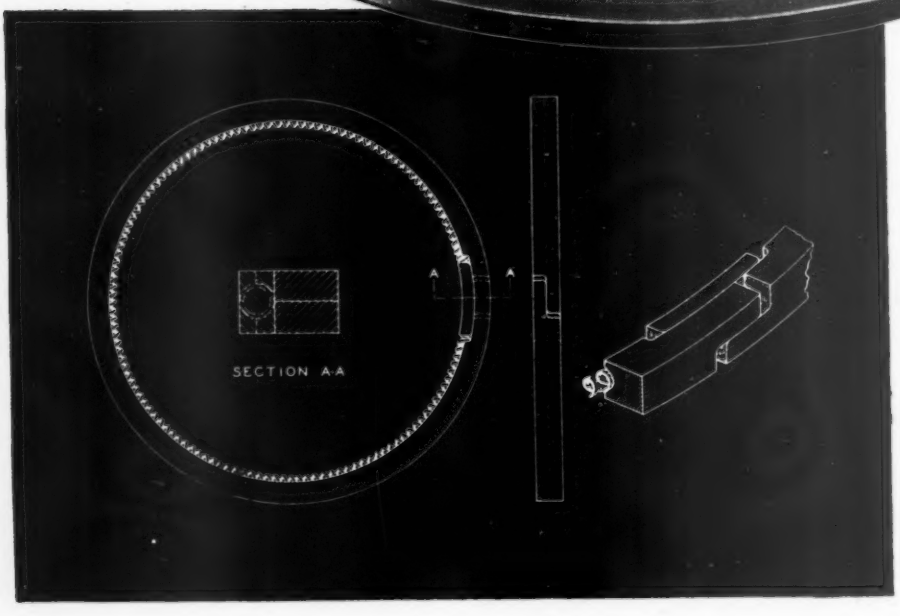
Existing Markets Won't Close Gap

Even to bring revenue in step with investment calls for about a 50 per cent increase in current production, or the annual marketing of some 145 million barrels of domestic crude. Judging from recent performance based on oil markets presently served, this increase in revenue may not be attained before 1956, even if helped out by revenue from the initial marketing of natural gas. Thus it becomes imperative that plans for opening up additional markets be developed at the earliest moment possible.

Unfortunately the only further markets of consequence are those where Canadian oil has to compete with foreign oil, namely, in the state of California and in the province of Quebec. Alberta oil has recently been barely able to compete at Vancouver with foreign oil, due to depressed tanker rates. The spread at California points would be greater and those at Montreal greater still, due to the longer pipe line distances for transportation past Vancouver and Sarnia.

Thus the need for cutting wellhead prices, first timidly suggested a year or so ago, has lately been looming as an urgent "must." Determination of how much of a cut is necessary, however, is an extremely complicated and delicate operation, involving concurrence of refiners, producers, and pipe line

Look to COOK



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To obtain more information on products advertised see page E-33

companies. The price cut would presumably have to be applied in two stages: the first to make Canadian oil competitive in the more immediate U.S. Pacific coast market, presently amounting to perhaps 50 million barrels yearly, and ultimately double this volume; the second and more drastic cut later to make it competitive in the 70 million barrel per year market at Montreal.

1954 Increase Less Impressive

After 7 years of spectacular growth, Western Canada's petroleum industry reached a "levelling off" stage during 1954. Survey crews were down to 140 from 165 the previous year. There was a 28 per cent drop in the first 9 months in Alberta completions, though Saskatchewan drilling exceeded that of 1953 by 12 per cent and a three-fold increase was shown in Manitoba completions. Drilling in the 3 provinces was thus slowed down to a more moderate rate in line with available markets. No substantial increase in proven reserves was recorded.

The trend in annual production for the full year was also down, showing only some 20/22 per cent over 1953 compared with a gain of 30 per cent in 1953 over the previous year. This was due to an unusually wet year on the prairies, to the poorest prairie grain crop in 11 years, which curtailed fuel sales for harvesting, and to the milder weather in Ontario last winter, which cut fuel oil consumption in that province. Total production for the year is expected to be between 96 and 98 million barrels however, compared with 81 million for 1953.

On the other hand, refinery capacity now operating, plus that planned for 1955, ended the year at an all time high in volume and value. Virtual self sufficiency in products will be achieved with completion of the 3 new refineries now building in Halifax, Montreal and St. Boniface, totalling 52,000 bbl capacity. Pipe line construction, though moderately lower than in 1953, promises to break all records in 1955-56.

There is a proved producibility or potential of 500,000 bbl daily from known reserves, or 60 per cent above indicated 1955 requirements. The pipe line systems are adequate to take care of producibility up to 1960, while ultimate capacity is only being 20 per cent used westward and 30 per cent eastward. Besides this, the shaking out of marginal producers by mergers and consolidations has left development in stronger hands. It is thus apparent that 1954 has been a year of consolidation, indicating that the industry has become stabilized, and is stronger and more soundly based.

The Author

H. G. Cochrane is a member of the Engineering Institute of Canada. After spending his early years on irrigation development in Alberta and Saskatchewan, he went east to build a number of large hydro-electric power plants in Quebec and Manitoba. He became interested in oil development in the late thirties while making preliminary studies and estimates of oil pipe lines to Lakehead and the Pacific Coast.

During World War II he conducted economic studies on scarce materials and services for the Canadian Government. He is presently with Power Corporation of Canada Limited at Montreal.

Smaller Gains Except in Saskatchewan and Manitoba

The 9 months growth in Alberta production for 1954 was disappointing. Pipe line movements east and west from Edmonton over the first 9 months exceeded the previous year's movement over the same period by only some 7000 bbl daily including the filling of loops. Fourth quarter movement probably pulled this gain up considerably. A repetition of the sharp increase experienced in the fall of 1953, when the Sarnia extension of the Interprovincial pipe line and the Trans Mountain pipe line came into operation, was not available to give a year end boost in 1954. However, the volume scheduled for the last months of 1954 westbound through the Trans Mountain pipe line was revised sharply upward to 80,000 bbl daily. This resulted from a stiffening of tanker rates, which if maintained could make Canadian oil competitive at current prices with foreign oil in Pacific Coast.

Saskatchewan's capacity to market what can be produced has been sharply curtailed due to the fact that medium crude has not been acceptable to existing refiners within transport range. This condition is gradually changing, however. Manitoba's production, though small compared with Alberta's, experienced a more than fourfold increase over 1953 in the first 9 months at a rate of nearly 2 million barrels yearly, and is expected to have a potential of more than triple this rate by 1956.

Production for the year in these two provinces at some 5 million barrels will be up some 60 per cent over 1953. Domestic markets are expected to absorb an additional 20,000 bbl daily by 1956, due to replacement of Alberta crude in the Winnipeg market. The opening of new pipe lines in Saskatchewan into Regina, to feed into the Interprovincial pipe, and across the international boundary to serve north central states, should add an export market of a further 20,000 barrels daily next year.

Thus there are reasonable grounds for expecting a growth of around 25 per cent in total production for 1955, namely to a total of about 125 million bbl or 340,000 bbl daily average throughout the year. Yet this improvement, though encouraging, will alone do little toward closing the ever-widening gap between investment and revenue, so necessary to stimulate exploration for the additional reserves to make Canada self sufficient in oil.

Bold Price Adjustments May Be Needed

Canadian crude is sensitive to fluctuations in its competitive position where it meets foreign supplies at the Pacific Coast, and in the big Quebec market if and when it is piped another 700 miles beyond Sarnia to Montreal. Four or five years hence, on completion of the St. Lawrence Seaway, it may have to compete with foreign oil at points on the Great Lakes where there are refineries.

At the time the Interprovincial pipe line was built in 1950-51, a cut in wellhead prices was required in return for the larger market in Ontario. Another small price cut was made in 1953, when the Trans Mountain pipe line went into operation. A third pirce cut of 9 cents was recently posted to balance the lower cost of U. S. crude at Sarnia on account of the 3 per cent discount on Canadian funds.

But such small price cuts unfortunately cannot solve the problem of what to do about Western Canada's present huge excess of producibility, and the way the growth of that producibility has been out-distancing the growth of available markets. Much bolder and intensive study of crude pricing may have to be made in order to find a solution to the industry's current problems, and to restore the spectacular rate of growth it has experienced over the past 7 or 8 years.

15-Cent Per Barrel Cut Suggested

It did not appear until November that any rise in ocean tanker rates could be expected in the foreseeable future, sufficient in itself to divert Canadian oil to U. S. Pacific Coast markets. The only events that could have helped the situation would be some international development, which would compel the diversion of Middle East oil elsewhere, or the offering of some other fluid cargoes that would attract tankers away from the present small-profit oil run. Neither of these alternatives appeared to be in prospect.

It was reported by the Petroleum Press (British) in its October issue, that by the end of 1955 an additional 6 million tons of tankers will have been delivered from world shipyards since June 1954. Thus the surplus would persist until either more scrapping occurred or until deliveries tapered off, or both, permitting tanker rates to rise to a more profitable level.

In some circles the suggestion had been advanced early last fall, for cutting Alberta wellhead prices 15 cents. This, it was claimed, could boost the Trans Mountain throughput up to 150,000 bbl a day, provided the transportation tariff was also reduced 15 cents. This lower pipe line tariff might well be possible, it was claimed, due to the greatly increased throughput. While the resulting 30 cent reduction might mean Canadian oil could have competed on Pacific Coast by tanker delivery, such a cut would not pay for additional pipe line transportation very far into California.

Later reports from crude oil marketing sources in Britain, however, have indicated that the spot tanker rate market has firmed up, and might reach USMC minus 30 per cent by year-end. On such a basis, and with current crude pricing, Alberta oil would soon be competitive with foreign oil in the Pacific Northwest States. Crude oil marketing experts believe this may happen during 1955.

Until the fleets of low rate tankers have completed their present charters and are taken up under the higher charter rates, the competitive position of Alberta crude will change only slightly. Yet the prospect may be sufficient to delay price cutting so as to compete in the northern Pacific State markets. Indeed, if the ultimate capacity of the Trans Mountain pipe could be attained with a small concession, the Montreal market would lose much of its attraction.

Montreal Market Calls for Cut

The Montreal market, which presently takes Arabian and Venezuelan oil either direct by tanker or through the pipe line from Portland, Maine, uses some 70 million barrels annually or an average delivery of 200,000 bbl a day. In order to compete at Montreal with Middle East oil, Alberta oil would have to sell there for slightly less. Middle East oil sold at Vancouver last summer at $3.11 per barrel. Foreign crude is slightly lower in Montreal, say roughly $2.90 average, without Panama tolls to contend with, and with a shorter ocean haul.

Considering the 2360-mile pipe line distance from Edmonton, if and when extended from Sarnia to Montreal, roughly three times the distance from Edmonton to Vancouver, on an additional volume of 200,000 bbl daily Alberta crude, based on today's wellhead prices, might cost in the neighborhood of $3.40 to $3.50 per barrel, delivered at Montreal. It would seem therefore, that a price cut on the order of 50 cents or thereabouts at wellhead would be called for in order to compete there with foreign oil. This would, of course, be reduced by a rise in tanker rates, and would be less any prior price cut necessary to make Canadian oil competitive on the Pacific.

Judging from the graphs on the accompanying chart, which shows investment in and revenues from the oil and gas industry in Canada for the past 8 years, and if assumed price cuts are reasonably correct, increasing the Pacific market to 75 million barrels a year from the present 25 million barrels would just about put current annual revenue in step with current annual investment. If and when Alberta could capture the Montreal market also, cumulative revenue might well catch up with cumulative investment and close the gap within another six or seven years.

Rising Volume May Help

There is another factor which may be of help. If the rapid discovery and development of Saskatchewan and Manitoba oil resources over the past year is continued, production from this source, some 400 miles closer to the Montreal market than Edmonton, could average down the cost of transportation to some extent and tend to reduce the necessary wellhead cuts in Alberta fields.

All of this is, of course, merely conjecture. It does not take into account the additional revenue that will accrue from the marketing of natural gas, nor any probable change in the current rate of investment. Nor can the course of world oil prices, oil consumption or fluctuations in the dollar be predicted. It does serve, however, in pointing up the advantages that could accrue to the Canadian oil industry from the opening up of these further oil markets.

Western Gas Pact Signed

Network costing $400,000,000 and connecting all major consuming areas west of the Rockies with West's large gas fields, has been effected within a three-way agreement.

Contract between Pacific Northwest Pipe Line Corporation, Westcoast Transmission Company, Ltd., and El Paso Natural Gas Company, will bring Canadian gas into California and open the way for serving Pacific Northwest states with gas from the San Juan Basin. Pacific Northwest will buy Canadian gas in addition to that brought from Southwest, selling a portion to El Paso Natural. El Paso will bring line from Idaho into central California consumer area.

Natural Gas a Competitor to Oil

The TransCanada natural gas project for exporting western gas to Winnipeg, Toronto, Montreal and intermediate Canadian markets, as well as to the Minneapolis area, now in the organization stage, may have a profound affect on the fortunes of Western Canada's oil industry. Though many oil producers will benefit handsomely by having a market for the gas they now waste in flares, this gas is likely to displace a considerable volume of fuel oil now consumed in oil burners.

Natural gas in the United States, once the unwanted stepchild of the oil industry, has been eating into markets traditionally served by oil. The same trend will be seen in Canada, though to a lesser extent because of the longer distances involved, and because proportionately the use of coal has not been replaced by oil to the same extent as in the United States.

Most U.S. utility companies have long waiting lists of gas customers. This is because gas is underpriced in relation to coal and oil. The price of gas is substantially the same as it was in prewar years, while the prices of coal and oil have roughly doubled in price. This is also true for Canada.

Besides this, oil products are now having to compete with LPG (propane, etc.) in the U. S., and in Canada as well. Some 165,000 U. S. tractors now use LPG at from 4 to 7 cents less per gallon than gasoline. The Union Pacific is experimenting with a propane-fired locomotive. Economists, however, look for the price of natural gas to increase until it reaches the level of other fuels on an energy basis.

No Pessimism for the Future

Notwithstanding the aforementioned problems facing the industry, no evidence of pessimism is to be found. Canada is enjoying a period of great development and expansion. Economists and leaders of industry predict a one third increase in population over the next 15 years, reaching 20 millions. Ranking today as the sixth largest manufacturing nation and the third largest trading nation, Canada is the most rapidly growing nation of the world. Per capita consumption of petroleum products is gaining rapidly. Thus there is ample assurance of adequate markets for Canadian oil in the years to come.

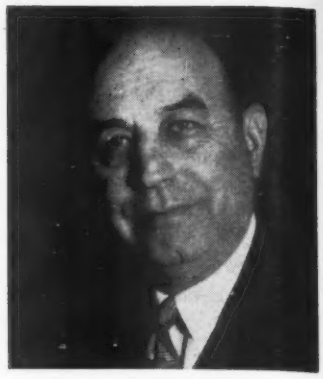
* * *

XUM

1. Know-How
2. Sound Economics
3. Public Understanding

Signposts for a Sound Economy*

Harry W. Bass tells Canadians the simple lessons U. S. operators have learned — usually the hard way



Harry W. Bass

FOR whatever value it may be, I welcome this opportunity to point out a few lessons we feel we have learned in the oil and gas producing business in the Southwestern part of the United States. As I attempt to summarize these lessons, they may seem quite simple, but somehow our history shows that we learned them the hard way. In many ways you in Western Canada are 20 or 30 years ahead of where we stood at comparable times in the period of "growing up" petroleum-wise in the Southwest.

Together we face the prospects of growing populations, higher standards of living with greater demands for low cost energy.

With this encouraging vista ahead of us, let's plot our course and make use of some recent lessons of history. But, first, let's look at the ingredients for a successful, oil-based economy such as you are rapidly developing here in Canada.

Based on our history in the Southwest, I believe they can be boiled down to these factors, each as essential to stability and dependability as the legs of a three-legged stool:

1. KNOW-HOW

By "know-how" I'm referring to the technology of finding, producing, transporting, refining, and marketing of oil and gas. Today's commonplace knowledge on the principles of behavior of oil in the reservoir was a sort of radical heresy in our industry not many years ago. Today's technology for the relatively high recovery of liquids from natural gas and the petrochemical business were pretty much in the laboratory stage prior to World War II.

Yes, this youthful Canadian oil industry's technological heritage is great. But at the risk of stating the obvious, I must warn you that we must not allow ourselves to become so dazzled by technological possibilities that we are blinded to economic realities.

2. SOUND ECONOMICS

For example, in Texas, we have made great strides in conservation of gas through construction of plants and building of pipelines but, I must say that some of our idealistic achievements conservation-wise did not—and could not—come about until they could be justified on a sound dollar and cents basis which came from greater markets for liquefied petroleum gases and higher prices of natural gas.

The hard core of decisions on the things we do must be forged under the stern pressure of consideration for the safety—plus an opportunity for growth —of each dollar involved. It is also axiomatic that these decisions must be made by those who also have the major responsibility for success of the project. This also explains why those who carry the responsibilty must also appear somewhat on the conservative or cautious side. It is for this reason that successful oil operators are very wary of subsidizing one phase of their enterprises at the expense of another. Each enterprise, and each phase of an enterprise must stand on its own merits as having a reasonable chance for success.

I have in mind two large enterprises in my home state where the operators perhaps became a bit bedazzled by processes that were technologically feasible. They were further encouraged by some rather reckless outside capital They built expensive plants—one for about $25,000,000—one for around $50,000,000. A number of things happened, including a rapid increase in the market price for natural gas which they had hoped to use for raw material. These enterprises had to go through a financial wringer and be shaken down to realities.

The subsidization of uneconomic enterprises has the effect of freezing capital and capital does not respond well to frosty conditions.

While we think of matters of public policy and general social welfare, as a lifelong independent operator I cannot refrain from calling your attention to another temptation that should be resisted: a condition of monopoly. Though many of us as individuals may privately aspire to achieve monopolistic positions, we must acknowledge that the great public benefits from oil and gas have been gained through competition. Through competition the public receives the net results of many judgments and many ambitions which are denied it by a monopoly, however well meaning or benevolent, whether private or governmental.

We had some painful experiences in Texas during the development of what is today a wholehearted industry and public support of conservation. When the forces of technology and sound economics were finally brought into balance, we saw the snuffing out of thousands of gas flares. When reservoir pressures were controlled by regulated production we saw oil in the ground become sound collateral for bank loans and dependable valuation for underwriting the financing of public school buildings; we saw permanent cities replace "boomtown" shacks.

3. PUBLIC UNDERSTANDING

The catalyst for bringing forth the best results from sound economics and technology is public understanding. Your fellow citizens across the continent shall be given the chance to gain a fundamental knowledge of the basic facts of life concerning the development of oil and gas. I sometimes fear we have waited in the U. S. until the industry has grown so mature and so complex as to almost defy description and until the public mind can only seem to grasp the legendary and fairy tale aspects centered around colorful, but not very significant individuals. You have a rare opportunity for encouraging your fellow citizens to grow up with the industry here in Canada.

I wish also to make this observation that nowhere in the economic history of the world does the oil industry have a parallel for contribution toward the rapid rise in standards of living throughout the globe. Let's go forth and tell our story. * * *

*Condensation of an address by Harry W. Bass, Dallas, president, Texas Mid-Continent Oil & Gas Association, before the annual meeting of the Canadian Petroleum Association at Calgary, Alberta.

Exploration, Drilling, Producing

Israel Wildcat Underway

Continuing far flung exploration under American guidance is seen in the recent start of a test in Israel 25 miles south of Beersheba. Projected to the 7500-8500 ft. depth range, the operation is a joint venture of Husky Oil and Bear and Stearns and Company, New York investment firm, the partnership operating as the Israel-American Oil Company. Well is the fifth wildcat now underway in Israel. Location is on a well defined anticline seven miles in length with an indicated closure of 1150 ft.

★ ★ ★

AIME Holds Austin Session

University of Texas engineers discussed means of recovering additional oil from depleted reservoirs at a regional meeting in Austin December 11. Two means of accomplishing the objective have shown promise in laboratory tests, they announced. One is the injection of gas under high pressure and the other the use of surface active chemicals which will be effective even in water wet sands.

★ ★ ★

Imports Gain

The IPAA has announced that the importing of oil reached a new high during the month of November, 1954, with foreign oil furnishing 14.5 per cent of the nation's supply. This, continues the report, was in the face of an increase in domestic producing capacity. A forecast for December, based on schedules submitted to the Texas Railroad Commission, showed that the trend would continue during December, with foreign oil expected to make up 14.6 per cent of the supply that month and the following months of January and February, 1955.

★ ★ ★

Boys Camp to Reopen

The R. M. Pyles Boys Camp, Porterville, California, will again be host to hundreds of youths, thanks to the generosity of Southern California's oil industry. Season will extend from June 13 to August 24. Deserving boys who would not otherwise be able to go to a summer camp are selected each year and enjoy a free two-week vacation at the high Sierra camp. Over 300 boys will be guests at the camp during 1955.

East Africa Test Started

Word has been received of the spudding of a wildcat on the island of Mafia off the coast of Tanganyika by Anglo-Iranian and the Shell Group. Location was made after intensive geological and geophysical surveys conducted in East Africa since 1951.

★ ★ ★

Montana Maps Available

USGS has designated Montana Bureau of Mines and Geology as agent for distribution of topographic and geologic maps of Montana.

Copies of Index to Topographic Mapping in Montana may be secured by writing to the Office of the Director, Montana Bureau of Mines and Geology, Montana School of Mines, Butte, Montana.

The Bureau has received a complete set of all topographic maps of Montana except those which are out of print. Maps will be sold at cost.

★ ★ ★

Drilling Success Ratio High

Twenty-two discoveries out of 54 test wells drilled last year—more than double the industry average—is the success ratio of Cities Service's drilling program for the first 10 months of 1954. The program for the year to date has netted the company an additional initial potential of 70,000 barrels of oil daily and an open flow potential of 1.5 billion cubic feet of gas daily.

★ ★ ★

Partnership Formed

W. S. Frisbie, president of Frisbie & Yancey Drilling Company, and C. J. Creekmore, president of Creekmore Drilling Company announce the association of a partnership for the completion of all contracts which Frisbie & Yancey Drilling Company and Creekmore Drilling Company are now drilling and the acquisition of all drilling rigs of Creekmore Drilling Company in Oklahoma, New Mexico, and Texas at the completion of present contracts. Frisbie & Yancey Drilling Company will then operate seven rotary drilling rigs in the Mid-Continent and Permian Basin areas. Creekmore Drilling Company will then continue operating its drilling rigs in the Rocky Mountain area. The above transaction was negotiated by Lucey Products Corporation.

Oregon Exploration Set

El Paso Natural Gas Company has announced intentions to drill a 6500-ft wildcat in Oregon. The location is on a farmout from Sinclair Oil and Gas Company, 10 miles northeast of Vail and 15 miles west of the Idaho border in Malheur County.

★ ★ ★

Dallas ASME Meet Held

On Wednesday, December 9, the initial luncheon meeting of the North Texas Petroleum Section of the ASME was held at the Baker Hotel, Dallas, with 45 members and guests present. Jack Crichton, president of Oil and Gas Property Management, spoke on the future of the petroleum industry.

As this section has just been organized, permanent officers have not yet been elected. Temporary officers of this section are: John M. Stevenson, chairman, Continental Supply Company; Bob Nelson, secretary, Continental Supply Company; M. A. Freeman, chairman of arrangements committee, Atlantic Refining Company.

R. W. Cox, Dallas Power and Light Company, chairman of the North Texas Section of the ASME, has also been actively supporting the organization of the Petroleum Section, as has J. W. Lacy, Texas Instruments Company, who is in charge of the arrangements for the Petroleum Mechanical Engineering Conference to be held in Dallas in the fall of 1956.

The next regular luncheon meeting of the Petroleum Section will be held Thursday, January 19, at the Baker Hotel. R. L. LeTourneau, vice president of R. G. LeTourneau, Inc., Longview, Texas, will speak on the new 2,000,000 off-shore drilling platform which his company is now building.

★ ★ ★

African Exploration Set

Exploration rights in British Somaliland, covering 11,380 square miles, have been acquired by Standard-Vacuum Oil Company through an assignment of rights held in that country by Moriqui Exploration Company. Standard-Vacuum has announced that it will continue and expand the geological activity started by the Moriqui firm. Geologists at the present time are undertaking an extensive surface study in the area to check the findings of a recent aerial survey.

XUM

BAKER *Tools for Today's Operations*

BAKER OIL TOOLS INC. — BAKER — SERVING THE WORLD

Here are a few of the most outstanding Baker Oil Tools for 1954. Complete details, illustrations and specifications are in your new 1954 Composite Catalog, starting on Page 435, where many other important Baker Products will be found.

▶ No other product has proved so successful for so many applications as the BAKER RETAINER PRODUCTION PACKER, which can be set on tubing, drill pipe, or on a wire line. Look on Page 496 of the 1954 Composite Catalog to learn how it is used for single-zone or dual-zone production; as a squeeze tool for acidizing or cementing; as a tubing anchor and as a bridge plug.

▶ For placing cement slurry, plastic, acid or other fluids, the BAKER RETRIEVABLE CEMENTER provides a safe, positive "Hold-Down Type" Packer which operates mechanically rather than by fluid pressure. Look on Page 495 of the 1954 Composite Catalog.

▶ BAKER CASING BRIDGE PLUGS can be set on tubing, drill pipe, or on a wire line to provide either a permanent or a temporary bridge plug which prevents either upward or downward movement of fluid or gas. Many other advantages are described starting on Page 474 of the 1954 Composite Catalog.

▶ No other product can equal the efficiency of the BAKER CEMENT WASH-DOWN WHIRLER FLOAT SHOE for safely floating-in and landing casing strings of any length. Removes bridges, washes the formation, and imparts a "whirling" action to the slurry. See Page 438 of the 1954 Composite Catalog.

▶ With BAKER DIFFERENTIAL FILL-UP SHOES (or Collars) the casing is filled automatically as it is being run, to within 90% of the fluid level of the annulus. Eliminates the dangerous "Ram Effect" which may break down a potential lost-circulation zone. Permits the introduction of the action of a back-pressure valve at the discretion of the operator, for floating (if desired) and for cementing. Ask any Baker office for brochure containing complete details.

▶ BAKER FLEXIFLOW FILL-UP SHOES (or Collars) permit filling the casing automatically as it is being run, while maintaining a relatively constant level of dry (unfilled) casing until the casing has been landed. It is then possible to bring the Bakelite Ball Valve into play as a back-pressure valve for floating and/or cementing when desired. This latest Baker development is illustrated and described in a folder available upon request from any Baker office.

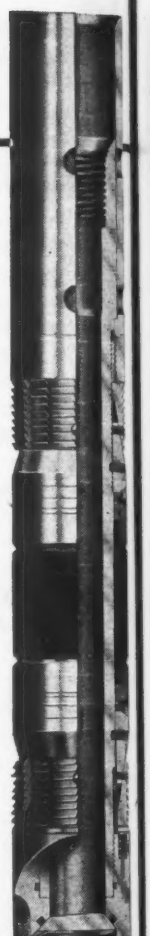
▶ For successfully placing cement or fluid at the place where it will be most effective, the BAKER CEMENT RETAINER has been "standard equipment" in International oil fields for many years. Read of its many uses starting on Page 474 of the 1954 Composite Catalog.

▶ The importance of having the I.D. of casing free from gun-shot burrs, hardened rotary mud and mill scale is evident from the rapidly increasing use of BAKER ROTO-VERT CASING SCRAPERS. Can be run easily and safely on drill pipe, tubing or a wire line, and leaves the "working surface" of casing clean and smooth for all future operations. Look on Page 517 of the 1954 Composite Catalog for details.

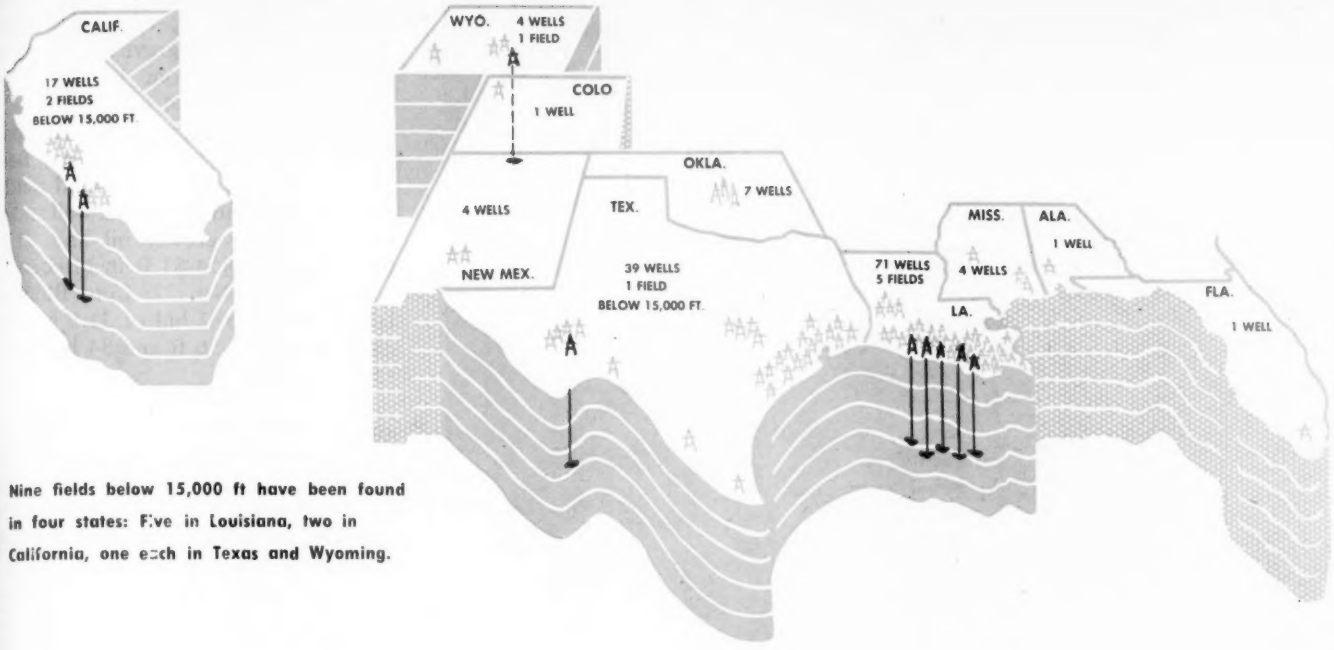
▶ When the time comes to center casing *positively*, and provide a uniform annular space for successful cementing, you need BAKER HINGE-LOK CASING CENTRALIZERS. Made in four ranges to exactly meet your casing programs, with many features not found in other centralizers. Interesting facts and illustrations start on Page 462 of the 1954 Composite (or Baker) Catalog.

▶ Controlled removal of the mud cake throughout the intervals to be cemented is positive and safe when BAKER WALL SCRATCHERS are used. The "scratching" action is minimized while running-in, but the spring-loaded wires with maximum reach dig in for best results on the upstroke. See Page 472 of the 1954 Composite Catalog.

▶ Any drilling man will tell you how the BAKER DRILL PIPE FLOAT VALVE lengthens the life of wire lines and brake bands by relieving weight; how it prevents pulling "wet" strings; how it prevents or minimizes accidents in case the drilling string should part. See for yourself on Page 534 of the 1954 Composite Catalog.



Baker Retainer Production Packer
Product No. 415-0



Nine fields below 15,000 ft have been found in four states: Five in Louisiana, two in California, one each in Texas and Wyoming.

Total wells in the United States drilled below 15,000 ft reaches 150 — averaging 3 miles depth and $580,000 cost

Operators Completed 53 Deep Wells in 1954

Ernestine Adams*

THE tremendous fact in deep drilling for 1954 is the number of wells that were drilled below 15,000 ft and the amazing increase over other years.

A total of 53 wells, more than half in Louisiana, went to 15,000 ft or deeper. There were only 24 wells of like depth drilled in 1953 and in 1952.

Deep wells in 1954 were more than double the number drilled in any other year.

This raised the total wells in the United States drilled below 15,000 ft to 150 wells in 10 states.

Operators drilled 450 miles for these 150 wells, averaging 3 miles per well. Footage for the 150 holes was 2,379,-940, or 15,866 ft per well.

Costs ran about $580,000 per well average not including such wildcats as Superior's 20,521-ft Wyoming well, Ohio Oil's 21,482-ft California well and Vasen's 20,450-ft Mississippi well.

Total cost for all 150 deep holes probably totals more than $90 million.

Variation in costs in different areas is shown in Table 1. Louisiana wells—and there are 72 of them—are pretty

*Management Editor.

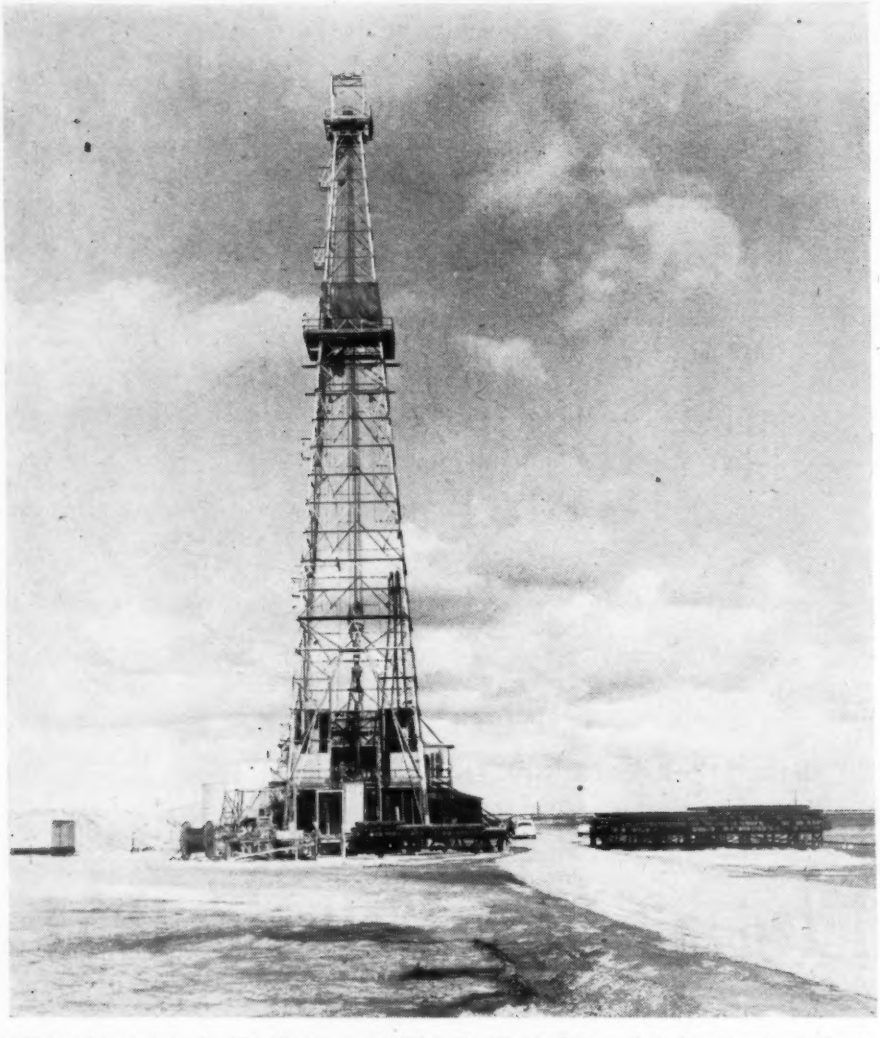
TABLE 1. Location and averages of wells drilled below 15,000 ft.

State	Number wells 1954	Total 15,000 ft holes	Completed as producers	Drilling time average days	Average bits per well	Deepest well	Mud costs, average	Well costs, average
Alabama	0	1	0	225	186	15,659	—	—
California	5	17	6	265	196	21,482	$85,000	$775,000
Colorado	0	1	1	420	322	15,041	—	—
Florida	0	1	0	485	144	15,155	—	—
Louisiana	33	72	47[2]	141	96	18,660	55,000	502,000
Mississippi	1	4[1]	0	—	166	20,450	—	—
New Mexico	2	4	3	375	—	16,705	—	—
Oklahoma	1	7	2	424	285	17,823	49,000	650,000
Texas	11	39	14	252	173	18,609	83,000	665,000
Wyoming	0	4	2	379	286	20,521	—	—
	53	150	75					

[1] One is George Vasen No. 1 Fee which began workover 9-6-54.
[2] Includes 3 shut-in gas wells.

TABLE 2. Number of wells drilled below 15,000 ft by years of completion.

Year	Wells drilled below 15,000 ft by date of completion	Average drilling time	Average bits per well	Mud costs, average	Well costs, well	Average depth	Deepest well	Deepest producer of 15,000 ft
1938	1	284	195	—	—	15,004	15,004	13,175
1945	4	490	222	—	—	15,870	16,655	13,175
1946	1	349	184	—	—	15,452	16,655	13,175
1947	8	267	181	$23,500	$570,000	15,891	17,823	13,904
1948	7	328	303	27,500	551,000	16,047	17,823	14,255
1949	10	222	199	62,500	534,000	16,421	20,521	15,530
1950	5	235	181	63,000	577,000	15,713	20,521	15,530
1951	12	178	116	54,000	521,000	15,822	20,521	15,530
1952	24	212	138	66,000	542,000	15,874	20,521	16,102
1953	24	229	150	79,000	719,000	16,366	21,482	17,895
1954	53	184	76	60,000	515,000	15,852	21,482	17,895



Still the deepest hole, the Ohio Oil Company's KCL-A No. 72-4 in Paloma field, Kern County, California, was suspended in October, 1953, and has been testing in shallower sands in 1954.

consistently lower in costs, both for wildcats and field wells.

The sharp upturn in costs for 1953 (Table 2) is due largely to less drilling in Louisiana that year than in Texas.

In 1954 average drilling costs were the lowest yet recorded. This was influenced by the large number of deep wells drilled in Louisiana.

Drilling time was not as low as in 1951, but almost reached that point. It took 184 days on the average to drill a deep well in 1954 compared to 178 days in 1951. Average bits per well showed improvement in bits and techniques by dipping far below any other year. An average of 76 bits per well were used in 1954, much less than the 116 in 1951 which was the record low to date.

PRODUCERS

Out of 53 deep wells this year 33 were completed as producers, proving again that deep wells not only supply valuable information but can pay out.

Shell found the deepest new pay in 1954 at Weeks Island field, Iberia Parish. W. G. Weeks No. 1 was completed at 17,140-52 ft in "Y" sand for 158 bbl a day of 40.6 gravity oil and 4838 MCF gas. This extended Louisiana's largest and deepest field.

In Louisiana 15 extensions or new oil sands were found, 7 of which were below 15,000 ft. Three were at Weeks Island, one each at Lake Washington, Dog Lake, Cote Blanche Island, Queen Bess Island.

In addition to its W. G. Weeks No. 1, Shell completed Gonsoulin-Minvielle State No. 3 also extending Weeks Island. It is producing 370 bbl a day oil and 469 MCF from the "W" sand at 16,852-62 ft.

Humble found new pay in the Weeks Island field at 16,834-44 ft. Rita Provost Minvielle No. 1 produced 410 bbl a day of 29.5 gravity oil and 400 MCF. Total depth was 17,637 ft.

John W. Mecom and Freeport Sulphur extended Lake Washington field with LL&E No. 1, which made 413 bbl a day of 45.3 gravity condensate and 1325 MCF from 15,130-8 ft. Total depth was 16,281 ft.

The Texas Company extended Dog Lake field in Terrebonne Parish a half mile with Unit 9-3, which produced 93 bbl a day of 44.8 gravity condensate and 3152 MCF from 15,560-73 ft. Total depth is 16,104 ft.

The same company found new pay below 15,000 ft in both Queen Bess Island and Cote Blanche Island fields. The former is shut in but the well tested 123 bbl of 44 gravity oil and 9130 MCF from 15,454-81 ft in Miocene.

State Lease No. 22, Cote Blanche Island, flowed 522 bbl of 31.3 gravity oil from 15,243-56 ft and 84 bbl from 15,709-810 ft.

Pan American Producing Company and Austral Oil Exploration Company, Inc., No. 1 Lacassine, Thornwell field, Cameron Parish, produced 50 bbl a day condensate and 3700 MCF from 9632-48; total depth is 15,043 ft. This extended the Thornwell field.

These wells found new pay above 15,000 ft in Louisiana:

John W. Mecom and Freeport Sulphur State Lease 2028 No. 3, Lake Washington field, Plaquemines Parish, 205 bbl oil from 13,210-32 ft; total depth 15,115 ft.

Stanolind Oil and Gas C. E. Gheens No. B-1, Raceland field, Lafourche Parish, 38 bbl condensate, 1411 CF gas from 12,900-10 ft; total depth 15,000 ft.

Union Oil Company of California, State Lease 540 No. 4-B, West White Lake field, Vermilion Parish, at a total depth of 15,005, produced 150 bbl condensate and 5000 MCF gas from 12,370-90 ft.

Stanolind Oil and Gas No. 1 Lillie LeBleu, Big Lake field, Cameron Parish, 175 bbl oil from 10,300 ft and 120 bbl condensate from 13,300 ft.

Humble Oil and Refining Company No. 2 Delta Securities, Inc., Bully Camp field, Lafourche Parish, found 293 bbl of 37.3 gravity oil and 199 MCF in the Miocene at 10,978-90 ft, with hole bottomed at 15,115 ft.

NEW OIL FIELD

Stanolind found a new deep oil field in Matagorda County, Texas. Its Sanborn No. 1 went to 16,120 ft and discovered Frio sand at 13,021-51 ft, which produced 103 bbl of oil and 4133 MCF gas a day.

Gulf Oil found 65,000 MCF gas at 12,606 ft in the Ellenburger in Reeves County, Texas. The wildcat, Toyah Unit No. 1, went to 15,038 ft. There was also some condensate.

Phillips Petroleum drilled two extensions at Puckett-Ellenburger gas field, Pecos County, Texas. Odom D-1 made 7000 MCF from 14,710-15,030 ft and Odom A-1 made 25 MCF from 14,942-15,324 ft.

Stanolind is completing an extension

TABLE 3. DESCRIPTION OF WELLS IN THE UNITED STATES DRILLED BELOW 15,000 FT

TD, ft Prod. depth	Company Well	Drilled by	Field County or parish	Completed Spudded	Drill time, days	Casing and cementing schedule	Mud program	Bits, rock, drag and diamond	Cores Drillstem tests	Deepest form. Producing form., thickness	Perforations, production, pressures, choke, GOR, gravity, etc.	Remarks
CALIFORNIA												
15,002 12,110	Continental Oil Grubb #561	Sun Drilling Co.	San Miguel Ventura	4-21-54 12-14-53	86		Emulsion	121R 1 Dia.	5C 6DS	Pliocene Repetto	Perf. 10,887-12,110 IP 647 b/d 29.6° 519 MCF GOR 794 FT-400.	This was in Shafter area.
15,068 D & A	Superior Oil 73-17 Russell	Company rig	Wildcat Kern	8-26-54 4-26-54	120		Emulsion	72 total	23 C	Pre-Cret basement complex		
15,630 D & A	Standard of Cal. Hardison Ranch 2-1	Rocky Mt. Drilling Co.	Fillmore Ventura	12- 9-54 8-29-54			Emulsion	98R				Well suspended.
15,761 Susp.	Lloyd Corp. WS-3	Drilling & Exploration	Ventura Av. Ventura	7-17-54 8- -52								Redrilled from 1998. Completing.
16,492	Lloyd Corp. Wm. Sexton #1	Drilling & Exploration	Ventura Av. Ventura	Comp. 7- 3-54								
LOUISIANA												
15,000 13,265	Texas Co. St. Lse. 301 #77		Caillou Is. Terrebonne	8- 2-54 4-24-54							Perf. 13,256-65′ IP 235 b/d 33.3° GOR 1705 FT 2500# Ch 1/8.	
15,000 12,900	Stanolind C. E. Gheens #B-1	Loffland Bros.	Raceland Lafourche	2-17-54 7-23-53		20″-115′/175x—13⅜″-2487′/950x—9⅝″-10,521′/700x—7″-13,772′/460x Lr 5″-13,537-14,585′/90x.	Red lime base oil emulsion.		143C 4DS	Miocene 30′	Perf. 12,900-10′ 4 jets and 4 bullets/ft IP 38 b/d cond. 1411 CF GOR 37,202 FT 3700 # Ch 1/8 T and ¼ B.	Sesmic selection, Extended field 1 mi. north. Tested 14,460 prod. 100% salt water. Salt dome structure.
15,003 13,300	Stanolind Lillie Le Bleu #1	Dixie Drilling	Big Lake Cameron	5- 7-54 11-30-53	129	18″-120′/300x—13⅜″-1666′/1150x—9⅝″-10,018′/500x—7″-13,032′/380x—927′ Lr 5″-13,728/150x.	Nat'l Phos to 9000′,lime base/oil		76C	Sand 20′ & 80′	Perf. 10,412-20′ and 13,414-20′. Dual comp. IP 175 b/d oil and 120 b/d cond. GOR 749 and 16,058 Ch 1/8 T and ¼ B.	Offset to discovery-extended field.
15,005 13,390	Union Oil of Cal. St. Lse. 540 #4-B	R. H. Gracey Drilling	W. White L. Vermilion	4- 2-54 12-28-53	83	10¾″-2395′—7⅝″-12,641′—open hole to 15,005′	High phos. ,lime mud.	53R	78SW		Perf. 12,370-90′/80 bullets. IP 150 b/d and 5MMCF-FC 250 # FT 4450 #.	Discovered new gas sand.
15,043 9,648	Pan American & Austral Lacassine #1	Crescent Drilling	Thornwell Cameron	10-14-54 6-20-54	128	13⅜″-2233′/1280x—9⅝″-9118′/1400x—7⅝″-12,049′/200x.	Lime base 12% oil emulsion.	40R 2D	79SW 1DS	Miocene 14′	Perf. 9632-40′-4/ft IP 50 b/d cond. 3.7 MMCF-FC 300# FT 2556 # SC 0 # ST 2608# Ch ¼″	Subsurface selection. Extended field from Jefferson Davis Parish.
15,115 10,990	Humble (Delta Securities #2)	Company rig	Bully Camp Lafourche	3-23-54 12-11-53	87	20″-207′—13⅜″-3485′—9⅝″-10,461′—7⅝″-11,983′.	Alk.-tannate lime, diesel oil, clay and starch		57C 6 hr DS	Miocene	Perf. 10,978-90′/72 jets. IP 293 b/d 37° and 199 MCF. GOR 680. FT 2050# Ch 1/8 T and ¼ B.	Subsurface selection. Discovered new pay.
15,115 13,232	John W. Mecom & Freeport Sulphur St. Lse. 2028 #3		Lake Wash. Plaquemines								Perf. 13,210-32′ IP 205 b/d 29.9° Ch 12/64.	Discovered new pay in salt dome field.
15,148 12,260	Superior-Rockefeller St. Lse. 2038 #9	Company rig	Deep Lake Cameron	5-29-54 10- 9-53	189	22″-143′—13⅜″-2035′—9⅝″-12,482′—7″ Lr 12,406-13,450′—4½″ Lr 13,376-14,677′.	10 lb/gal to 17 lb/gal				Perf. 12,250-60′/60 jets. IP 177 b/d 45.6° and 9565 MCF. GOR 58,724 FC 3944 Ch 22/64.	Shut-in.
15,220 15,138	Shell Provost #1 State Unit #1	Company rig	Weeks Island Iberia	10-20-53 7-27-53	70			63	18C	U. Sand 62′	Perf. 15,154-78′/96 jets. IP 521 b/d and 585 MCF. GOR 1123 FC 1850# ST 3500# Ch 12/64.	Field well in famous Weeks Island salt dome field.
15,234 D & A	Phillips Pet. St. Lse. 222 #1	Prince Drilling	Gate Island St Bernard	4-25-54 10-14-53	121	20″-243′/500x—13⅜″-1829′/1200x—9⅝″-10,107′/1500x-5½″-10,306′/200x	Lime base.	53R 1D	6DS			Wildcat in Gate Island area.
15,264 13,437	Superior Oil L.L. & E Unit 12 #2	Company rig	Four Isle Terrebonne	8-19-54 deepened		18″-105′—13⅜″-1686′—9⅝″-10,920′—7″-14,028′—4½″ Lr 13,959-15,264′					Perf. 13,422-37 IP 5949 MCF GOR 33,724 FT 2510# Ch 22/64.	Well originally drilled to 14,220′ in 1947. Was deepened, plugged back and recompleted in same range.
15,370 8,294	Gulf Florence Timolat		West Bay Plaquemines	10- 2-54 5-29-54					1DS		Perf. 8264-94′/120 jets IP 3620 MCF Ch ¼″.	Shut-in gas well.
15,400 15,110	Texas Co. St. Lse. 340 #24		CoteBlancheIs. St. Mary	7-13-54 3-24-54							Perf. 15,088-110′/88 jets IP 61 b/d 26.7° GOR 1229 FT 70 Ch 15/64″.	Field well in deep Cote Blanche Island field.

TABLE 3. DESCRIPTION OF WELLS IN THE UNITED STATES DRILLED BELOW 15,000 FT (Continued)

TD, ft Prod. depth	Company Well	Drilled by	Field County or parish	Completed Spudded	Drill time, days	Casing and cementing schedule	Mud program	Bits, rock, drag and diamond	Cores Drillstem tests	Deepest form. Producing form., thickness	Perforations, production, pressures, choke, GOR, gravity, etc.	Remarks
						LOUISIANA (Continued)						
15,420 15,246	Texas Co. St. Lse. 340 #23		CoteBlanche Is. St. Mary	4-16-54 11-16-53							Perf. 15,228-46'/72 jets IP 324 b/d 25.8° GOR 864 FT 1300# Ch 11/64".	Field well.
15,423 D & A	Pan American Prod. Continental Ld. & Fur. Co. #1	Harry L. Edwards Drilling	Wildcat Terrebonne	10-12-54 5-30-54	135	20"-160'/300x—9⅝"-10,782'/1350x—7"-14,019'/300x.	Lime base 7% oil emulsion 17 lb/gal.	50R 1D	67SW 2DS			
15,483 14,042	Texas Co. St. Lse. 188 #148		Caillou Island Terrebonne	 5-11-54							Perf. 14,028-42' IP 227 b/d 44.6° GOR 13,130 FT 3300# Ch 5/16".	Field well.
15,508 Shut in	Texas Co. St. Lse. 1246 #C-5		Bay St. Elaine Terrebonne	2- 5-54 1- 6-53							Perf. 14,620-22' and 14,600-10'	
15,600 11,990	Shell Continental Ld. & Fur. Co. #9	Company rig	Turtle Bayou Terrebonne	8-26-54 3- 6-54	99	20"-121'/200x—13⅜"-2528'/350x—7⅝"-10,595/500x—7⅝"-11,900/469x.				BB sand 26'	Perf. 11,975-90' IP 138 b/d 49° and 6529 MCF. GOR 47,312 FT 1100# Ch 11/64".	Field well.
15,605 15,506	Shell Smith-State Unit D #2	Company rig	Weeks Island Iberia	11- 9-54 8-10-54	77	16"-127'/200x—10¾"-4012'/300x—7⅝"-15,320'/425x—5" Lr 15,280-590'/125x.			3DS	"V" sand	Perf. 15,531-43 and 15,548-54/72 jets. IP 156 b/d and 4143 MCF GOR 26,558 FT 4725 Ch 12/64".	Field well.
15,734 13,570	John W. Mecom & Freeport Sulphur Cockerell #20	Lake Washington Plaquemines					Salt dome structure.					Salt dome structure.
15,826 15,256	Texas Co. #22 State Lease		CoteBlanche Is. St. Mary							Miocene	Perf. from 15,243-56' and 15,709-810', IP 522 b/d, 31.3° FT 2100, Ch 10/64".	New pay.
15,990 J & A	Superior La Terre Company A #4	Co. Barge W. M. Keck, Sr.	Bayou Penchant Terrebonne	3-26-54 12-27-53	85	20"-157'—13⅜"-2000'—9⅝"-11,800'—6⅝" Lr-11,720-14,717'.	10 lb/gal to 20 lb/gal					Field well.
16,010 D & A	Shell La. Land & Exploration #1	Gulf Coast Drilling	Valentine Lafourche	5-11-54 1- 8-54	119							Wildcat. Site was selected by seismic and subsurface.
16,045 15,481	Texas Co. St. Lse. 356 #12		Queen Bess Is. Jefferson	7-15-54 2- 6-54						Miocene	Perf. 15,454-81'/108 jets. IP 123 b/d 44° and 9130 MCF GOR 74,000 FT 5125# SC 6250# Ch 10/64".	Discovered new pay. Now shut in.
16,104 15,573	Texas Co. Dog Lake Unit 9 #3		Dog Lake Terrebonne	4-14-54 10-29-53							Perf. 15,560-73' IP 93 b/d 44.8° and 3152 MCF GOR 44,200 FT 4900#, Ch 10/64".	Extended field ½ mile northwest.
16,312 13,948	Texas Co. St. Lse. 340 #25		Cote Blanche St. Mary	12- 6-54 8-10-54		16"-120'/100x—10¾"-3007'/800x—7⅝"-14,799'/700x.					Perf. 13,934-48' IP 321, 26.1° GOR 2369 FT 3000# Ch 9/64".	
16,281 15,138	John W. Mecom & Freeport Suplhur L.L. & E. #1		L. Washington Plaquemines	10-13-54 5-22-54						Sandy shale	Perf. 15,131-8' IP 413 b/d 45.3° and 1325 MCF GOR 2324 Ch 7/64".	Extended field. Salt dome structure.
16,296 J & A	Sun Oil D. S. & B. #37		Chacahoula Lafourche	5- 8-54 9- 7-53								Couldn't recover fish.
16,500 13,831	Texas Co. St. Lse. 121		Caillou Island Terrebonne								Perf. 13,064-82' and 13,816-31'.	Shut-in gas well. No gage.
16,889 D & A	Richardson & Bass St. Lse. 1891 #3-E		Wildcat Plaquemines	5-26-54 12-30-53								Near Lake Washington field.
16,962 16,862	Shell Gonsoulin-Minvielle St. Unit 3	Company rig	Weeks Island Iberia	11- 1-54 8-10-54	71	16"-120'/200x—13⅜"-3039'/300x—9⅞"-13,937'/425x—7"-16,962'/120x.			13C	"W". Sand	Perf. 16,852-62'/40 jets IP 370 b/d and 469 MCF GOR 1268 FT 2650# Ch 9/64".	Now deepest oil producer in world.
17,030 D & A	Texas Co. Mrs. C. D. Mire et al Unit 12 #1		Valentine Lafourche	6-11-54 1-20-54								Temporarily abandoned.
17,637 16,844	Humble-Rita Provost Minvielle #1	Company rig	Weeks Island Iberia	6- 2-54 2- 8-54	94	20"-170'—13⅜"-3538'—9⅝"-14,514'—7"-17,605'.	Alkaline-tannate. 10.6 lb max.		21C	Miocene Miocene	Perf. 16,834-44'/40 jets IP 410 b/d 29.5° and 400 MCF GOR 974 FT 3000#.	Subsurface geology selection. Found new pay in Weeks Island field.
17,647 16,824	Humble-Rita Provost Minvielle #2	Company rig	Weeks Island Iberia	10-28-54 7- 3-54	87	20"-151'/225x—13⅜"-2737/800x—9⅝"-14,536'/500x—7"-17,632'/500x	Alkaline tannate oil emulsion	76R	65SWC 1DS	Miocene Miocene	Perf. 16,824-40'/64 jets IP 314 b/d 30.4° and 250 MCF GOR 793 FT 1700# Ch 5/16".	

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THE PETROLEUM ENGINEER, January, 1955

TABLE 3. DESCRIPTION OF WELLS IN THE UNITED STATES DRILLED BELOW 15,000 FT (Continued)

TABLE 3. DESCRIPTION OF WELLS IN THE UNITED STATES DRILLED BELOW 15,000 FT (Continued)

TD, ft Prod. depth	Company Well	Drilled by	Field County or parish	Completed Spudded	Drill time, days	Casing and cementing schedule	Mud program	Bits, rock, drag and diamond	Cores Drillstem tests	Deepest form. Producing form., thickness	Terforations, production, pressures, choke, GOR, gravity, etc.	Remarks
						LOUISIANA (Continued)						
17,787 17,152	Shell W. G. Weeks #1	Company rig	Weeks Island Iberia	8-10-54 3-11-54	134	20"-120'/100x—13⅜"-3007'/350x— 9⅝"-14,070'/500x—7"-17,460/600x.				"Y" Sand 79'	Perf. 17,140-52'/48 jets IP 158 b/d 40.6° and 4838 MCF GOR 30,542 FT 5360# Ch 11/64.	Deepest oil production found in 1954. Extended field.
						MISSISSIPPI						
15,244 D & A	Gulf-Panuco W. B. Purser #1	Tri-State Drilling	Wildcat Copiah	4- -54 11- 8-54	195	20"-180'—13⅜"-1162'—9⅝"-8973'- open hole to TD.	High ph. oil emulsion below 9000'	98R 21 Dia.	37C	Hosston		Well was drilled to 14,515' by Panuco taken to TD by Gulf.
						NEW MEXICO						
15,584 6,122	Richardson & Bass R. H. Legg #1		Wildcat Eddy	5-11-54 7-10-53		20"-425'/700x—13⅜"-3627'/950x— 9⅝"-9026'/1500x.					PB 6122' IP 67 b/d 42.8° GOR 639. Treated with 1000 gallons acid and 2000 gallons sandfrac.	On pump. Discovered new field.
16,705 P & A	Richardson & Bass Harrison Fed. #1		Wildcat Eddy	5-22-54 7-22-52		20"-557'/750x—9⅝"-10,076/2711x— 7"-16,626'/1150x.				Devonian to 16,622	Perf. 12,320-35' PB 6135.	
						OKLAHOMA						
15,675 D & A	Pasotex Pet. & Anderson-Prichard Underhill #1	Noble Drilling	Wildcat Coal	9- 2-54 10-17-53	294	13⅞"-663'/600x—9⅝"-10,995'/800x and 300 CF Strata Crete.	Low ph. oil emulsion	211R 8 Dia.	22C 2DS	Basal Oil Creek sand		Seismic selection.
						TEXAS						
15,000 D & A	Humble No. 1 State tract 692	Kerr-McGee	Wildcat off Aransas	12- 2-54 7-11-54	92		Lime oil emulsion	40R 1D	167SW 1 prod. 4DS	Frio		Site selected by geophsical data.
15,038 12,606	Gulf Oil Toyah Unit #1	Southeastern Drilling	Wildcat Reeves	10-16-54 12-29-53	219	16"-1044'/1000x—10¾"-3870'/3230x —7⅝"-12,563/750x.	Chem. 8.4 lb to 10.8 lb vis. 32-75	189 total	7C 21DS	Ellenbuger Dol. Top Ellenburger	PD 12,606' treated with 9000 gal acid IP some cond. and 65 MMCF 2½" tubing.	Site selected by subsurface, magnetic, gravity, seismic.
15,294 Closed	John W. Mecom Boyd et al #1		Wildcat Liberty									
15,280 15,303	Phillips Pet. Odom #D-1	Company rig	Semi WC. Pecos	10-21-54 3- 4-54	172	13⅜"-1032'/745x—8⅝"-7649'/3030x —5½"-15,277'/2350x.	10.1 lb. 45 visc.	143R 445 Tot.	4DS	Ellenburger Ellenburger	Perf. 180/14,710-90'—300/14,870-920'—360/14,970-15,030'. Total acid. 47,500 gal 7 MMCF-ST 3291.	Completed as a gas well.
15,324 15,324	Phillips Pet. Odom #A-1	Big Chief Drilling	Puckett-Ellen Pecos	12-10-53 2-16-53	261	13⅜"-999'/668x—9⅝"-5099'/1850x —5½"-14,942'/2300x.	10.1 lb. 88 visc.	245R	6DS	Ellenburger	Prod. 25 MCF, 14,942-15,324' FT, 4100#, Shut-in FT 4350#.	Extended gas field.
15,519 D & A	Texas Co. Corbett #2		Wildcat Willacy	5-24-54 3-15-54	39							
15,815 D & A	Gulf Oil 319 O'Brien	Zephyr Drilling	Wildcat Ward	4-23-54 3-26-53	394	13⅜"-820'/800x—9⅝"-3180'/1800x —7⅝"-12,495'/3625x.	Chem. 85. to 10.6 lb vis. 33-130	334R 2 Dia.	33C 39DS	Ellenburger Dol.	Treated with 3000 gal 15% N E acid.	Temp. Abandoned.
16,087 13,675	Stanolind Mary Fall #1	Prince Drilling	Wildcat Matagorda	10- 6-54 3-20-54	116	7"-14,570'.	Lime base	69 total	2C	Lower Frio Middle Frio	Perf. 13,527-42' and 13,675-86'/108 jets. Well in process of completing 12-13-54.	Site selected by seismic and subsurface on flank of deep-seated dome. Extends field.
16,118 D & A	Phillips Pet. Puckett #F-1	Loffland Bros.	Wildcat Pecos	2-18-54 3- 1-53	549	13⅜"-960'/642x—⅝"-5/210'1790x. 1	0.8 lb. 98 visc.	322R	8DS	Ellenburger Dry		
16,120 13,050	Stanolind Sanborn #1	Prince Drilling Co.	Wildcat Matagorda	3- 1-54 9-29-53	153	13⅜"-2535'/1600x—9⅝"-9585'/1500x —7"-13,788'/500x—5"-13,110'/250x.	Lime base below 7000'. Graphite & oil emulsion below 9600'.		5C 50SWC 1DS	Frio sand 30'	Perf. 13,021-51'/120 jets IP 103 b/d 4133 MCF. Pack FT 5710 ST 7250 GOR 40,000 Ch ¼".	Dome structure. Seismic and subsurface selection.
16,514 J & A	Magnolia W.W. Rugeley #1		Wildcat Matagorda	9-20-54 6-12-54		20"-300'/500x—13⅜"-1530'/1000x.			46C			Stuck drill pipe left in hole.

Abbreviations: x = sacks of cement — R = rock — D = drag — Dia. = diamond — C = core — DS = drillstem — SWC = side wall core — GOR = gas oil ratio — IP = initial production — FC = flowing casing pressure — FT = flowing tubing pressure — SC = shut-in casing pressure — ST = shut-in tubing pressure.

TABLE 4. Producing depths of wells drilled below 15,000 ft.

Producing Depth, Ft.	No. Producers	Producing Depth, Ft.	No. Producers
4- 5,000	1	11-12,000	3
5- 6,000	1	12-13,000	9
6- 7,000	3	13-14,000	12
7- 8,000	1	14-15,000	7
8- 9,000	4	15-16,000	20
9-10,000	3	16-17,000	5
10-11,000	2	17-18,000	5
TOTAL PRODUCING WELLS			76

TABLE 5. Fields with production below 15,000 ft.

Field	County or Parish	State	No. wells producing below 15,000 ft.
Weeks Island	Iberia	Louisiana	16
Cote Blanche Island	St. Mary's	Louisiana	3
Queen Bess Island	Jefferson	Louisiana	1
Dog Lake	Terrebonne	Louisiana	1
Lake Washington	Plaquemines	Louisiana	1
North Coles Levee	Kern	California	1
Wasco	Kern	California	1
Puckett-Ellenburger	Pecos	Texas	3
West Poison Spider	Natrona	Wyoming	2

to its Sanborn discovery Mary C. Fall No. 1 went to 16,087 ft and production depth is 13,527-675 ft.

FIELD WELLS

Another 15 wells below 15,000 ft total depth were completed as producers in fields. Continental Oil Grubb No. 561 in San Miguel field, Ventura County, was the only one in California.

Richardson and Bass completed the only one in New Mexico; it was in Eddy County.

The remainder were scattered in Louisiana fields: Shell had one in Turtle Bayou field producing at 11,975-90 ft and two in Weeks Island at 15,506 ft and 16,824 ft, respectively.

Superior Oil completed one in Deep Lake field at 12,260 ft and one at Four Isle field at 13,437 ft.

Texas completed three producers in Cote Blanche Island field from 13,948 ft, 15,110 ft, and 15,246 ft. The company also had two in Caillou field, producing from 13,265 ft and from 14,042 ft, and one in Bay St. Elaine field completed as a shut-in potential gas well.

Another shut-in gas well is that of Gulf in West Bay field. It went to 15,370 ft and the gas sand is at 8264-94 ft.

John W. Mecom and Freeport Sulphur completed a producer from 13,570 ft in Lake Washington field.

PRODUCTION DEPTHS

Of 30 wells producing from below 15,000 ft, 13 were completed in 1954. All of these were in Louisiana except two, which were in Pecos County, Texas (Table 5).

By far the largest number of deep producers are in Weeks Island, Iberia Parish, Louisiana, where 16 wells now produce from below 15,000 ft. Most of these are good producers; a half dozen came in for more than 500 bbl a day and several for almost that.

Cote Blanche Island, St. Mary's Parish, Louisiana, has three wells producing from below 15,000 ft, all brought in in 1954.

For the first time 3 more fields in Louisiana have one well each producing from below 15,000 ft. They are: Lake Washington field, Plaquemines Parish; Queen Bess Island field, Jefferson Parish; and Dog Lake field, Terrebonne Parish.

Puckett-Ellenburgr field in Pecos County, Texas, has a total of 3 wells below 15,000 ft which are producers.

West Poison Spider, Natrona, Wyoming, had two deep producers.

California had one below 15,000-ft producer in Wasco field and one in North Coles Levee field, which made the record production depth of 17,895 ft last year.

DEEP WELL OPERATORS

Thirty-four operators are listed in Table 6, who have drilled from one to 23 wells below 15,000 ft. Many more companies have entered deep drilling operations by partnerships or agreements to supply acreage, financing, etc. Eighteen of the 34 operators drilled deep wells in 1954.

The Texas Company, Shell Oil, Phillips Petroleum, Superior Oil, and Gulf Oil have drilled 83 deep wells, more than half of the total holes that have passed the 15,000 ft depth.

With 12 deep wells this year, The Texas Company leads the list, passing Shell for the first time.

DRILLING CONTRACTORS

Not all operators named their drilling contractors and some companies ran their own rigs. Superior drilled one deep one from its barge *W. M. Keck, Sr.* in South Louisiana.

In spite of this there were 16 different contracting companies who drilled wells below 15,000 ft, some drilling two and three.

ACKNOWLEDGMENT

Deep-drilling operators have generously supplied valuable data on wells in this eighth annual survey of deep drilling. We fully appreciate the amount of effort required to give us this fine cooperation and hope that the operators receive full benefit from this shared information.

Because of the great expense involved in this type of drilling, information that helps to plan and execute such a project is worth study. No operator lightly consigns more than a half million dollars to one well; data here should provide some guidance.

TABLE 6. Operators of wells drilled below 15,000 ft.

Company	Have drilled, number	Drilled in 1954, number	Total
Abercrombie, J. S.	1	0	1
Brazos Oil and Gas Co.	1	0	1
Continental Oil Co.	2	1	3
Denver Product & Ref.	1	0	1
Gulf Oil Corp.	6	5	11
Humble Oil and Refining	5	4	9
LaGloria Corporation	1	0	1
Lion Oil Co.	1	0	1
Little Nick Oil Co.	1	0	1
Lloyd Corp.	0	2	2
Magnolia Petroleum	5	1	6
Mecom, John W.[1]	0	4	4
Mountain Fuel Supply	1	0	1
Ohio Oil Co.[2]	1	0	1
Pasotex Petroleum[5]	0	1	1
Pacific Western	1	0	1
Phillips Petroleum	13	3	16
Placid Oil	1	0	1
Pure Oil	3	0	3
Pan American Production[4]	0	2	2
Quintana	1	0	1
Richardson & Bass	6	3	9
Richfield Oil	1	0	1
Shell Oil	16	5	21
Standard of California	4	1	5
Standard of Texas	1	0	1
Stanolind	2	4	6
Sun Oil Co.	0	1	1
Superior Oil	8	4	12
Texas Company	11	12	23
Tide Water Associated	1	0	1
Union of California	0	1	1
Union Producing Co.	1	0	1
Vasen, George[3]	1	0	1
Total	97	53	150

[1] Three with Freeport Sulphur in Louisiana.
[2] This well suspended October, 1953; was testing at end of 1954.
[3] Work over in process.
[4] With Austral Oil Exploration.
[5] With Anderson-Prichard.

In California Drilling and Exploration, Inc., Sun Drilling Company, and Rocky Mountain Drilling Company had deep well contracts. Noble Drilling Corporation drilled one in Oklahoma.

Southeastern Drilling Company, Big Chief Drilling Company, Kerr-McGee, and Prince Drilling Company drilled deep holes in Texas.

Loffland Brothers Company, R. H. Gracey Drilling Company, Dixie Drilling Company, and Crescent Drilling Company were among those with contracts for deep wells in Louisiana.

DEEP FOREIGN WELLS

Only reported well outside the United States drilled below 15,000 ft is that of Richmond Oil Company, drilled to 15,539 ft in the Choco Pacific Area, Colombia. The hole was dry and has been abandoned.

Four wells are known to have been drilled below 15,000 ft in Venezuela, none completed as a producer.

1954 AND 1955

Last year brought no drilling or production depth records. Records were for total wells, number of producers completed, and the fact that in nine different fields wells are producing or have produced oil or gas from below 15,000 ft.

This year of 1955 may not bring new records but it will doubtless see an increase in deep wells. The trend is down, down, down. * * *

Twenty years in growing, interest in the MATADOR ARCH area of West Texas is now developing into a full-blown exploration program promising . . .

locations for tomorrow

WILLIAM C. HAYES

Averaging over 6 discoveries a year since 1951 and producing 7 new fields with 62 wildcats in 1953, this major structural feature offers a fertile field for exploration

SINCE 1932 a considerable number of wells drilled along a west-southwest trend in the southern high plains of Texas have encountered Precambrian rocks at comparatively shallow depths. Earlier publications have referred to this trend of highs as a western extension of the Red River uplift, and more recently it has been called the Matador trend, (uplift, range, ridge, archipelago, and arch Fig. 1). It has been named from the location of the early wells drilled on the Matador Land and Cattle Company's ranch in Cottle County.

In this paper the structural feature shall be referred to as the Matador arch. Uplift, trend, and ridge imply little as to the structural or geologic nature of the feature. If one is referring to the Precambrian structure, range or archipelago might be a more desirable term, but because arching of the younger Paleozoic beds over the structure is prominent and because of the prevenient usage of the term arch, it is suggested that it be retained and the other terms mentioned above no longer be used in referring to the Matador structure.

An important characteristic is the wide range in relief of the Precambrian along the arch. This allowed seas to be continuous, at various times in the Paleozoic, through gaps between the highs from the northern portion of of the Midland basin to the Palo Duro basin on the north.

To the east-northeast the structure is essentially continuous with the Electra arch; and to the southeast with the gently sloping Concho platform. If projected westward the trend of the Matador arch extends into New Mexico and passes in close proximity to Tertiary intrusives (Railroad Mountain) and on westward toward the Capitan Mountains.

Although a distinctive feature is the series of highs and lows along the structure, present data indicate that faulting of considerable magnitude has occurred along the south margin of the structure in Lamb and Hale counties and possibly along the north margin in Motley and Cottle counties.

The earliest well in this area to encounter a Precambrian high was the Merry Brothers and Perini, No. 1 Purcell drilled in southwest Cottle County. The only reference in the geologic literature of the area to mention this well as late as 1932 stated that it "affords an important record since it shows that the Red River uplift extends westward through Cottle County."[11]

By 1942 wells had encountered basement at comparatively shallow depths in southeastern Hale and southeastern Lamb counties, Texas, and in Roosevelt County, New Mexico, but the nature of the "uplift" had not been revealed at that time. By many it was referred to as a broad arch whereas others postulated the presence of a buried "ridge" similar to the Red River uplift or the Amarillo uplift.

The earliest production directly associated with the structure of the Matador arch was from the Anton-Irish field, Hale and Lamb counties, discovered in 1944. Even though a comparatively few fields are directly associated with the structure it appears that the Matador arch is indirectly an important structural control for many of

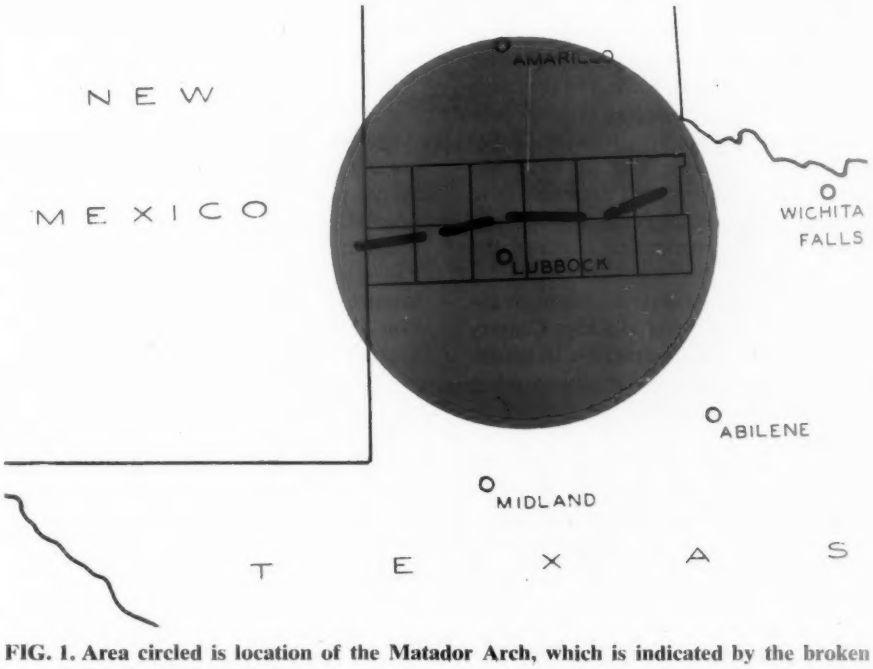

FIG. 1. Area circled is location of the Matador Arch, which is indicated by the broken line in the county area.

EXCLUSIVE

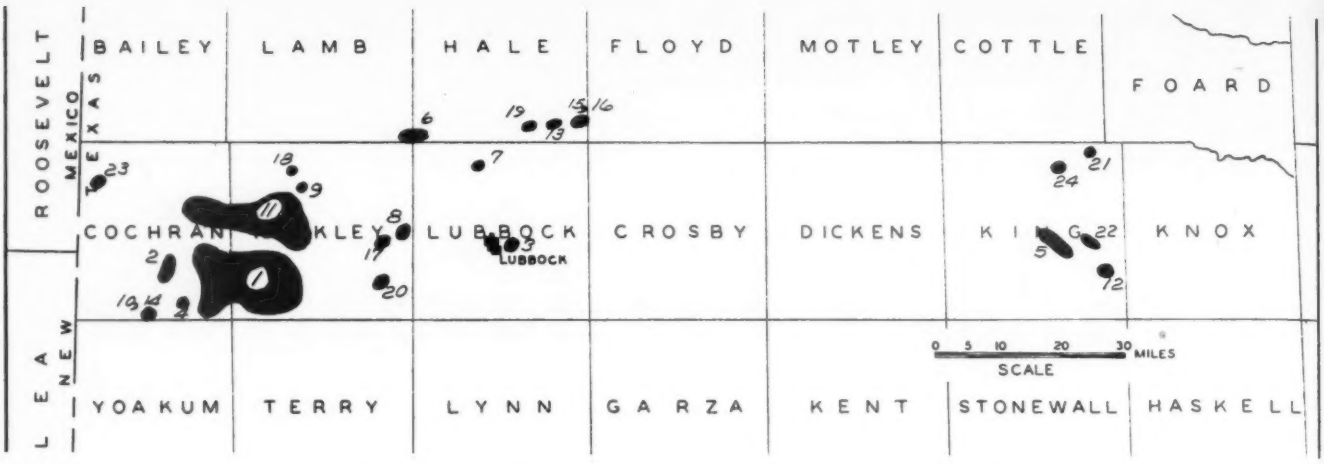

FIG. 2. Oil fields of the Matador Arch area (To 1952). See Table 1 for field data.

TABLE 1. Oil fields of the Matador Arch area.

No.*	Field name	County	Date	Prod horiz	Prod depth
1.	Slaughter	Hockley, Cochran	1936	San Andres	4950
2.	Dean	Cochran	1937	San Andres	4990
3.	Lee Horrison	Lubbock	1941	Clear Fork	5000
4.	Rhodes	Cochran	1941	San Andres	5050
5.	Bateman Ranch	King	1943	Cisco	3530
				Canyon	5050
				Strawn	5330
6.	Anton-Irish	Hale, Lamb	1944	Clear Fork	5990
7.	Craven	Lubbock	1944	Clear Fork	6050
8.	Smyer	Hockley	1944	Clear Fork	5850
9.	Yellowhouse	Hockley	1944	San Andres	4590
10.	Landon	Cochran	1945	San Andres	5040
11.	Levelland	Hockley, Cochran	1945	San Andres	4750
12.	Ross Ranch	King	1945	Strawn	5240
13.	Petersburg	Hale	1947	Cisco	6990
14.	Landon-Strawn	Cochran	1947	Strawn	10380
15.	Arrick-Pennsylvania	Floyd	1948	Cisco	5900
16.	Arick-Wolfcamp	Floyd	1948	Wolfcamp	4810
17.	West Smyer	Hockley	1948	Clear Fork	5850
18.	North Yellowhouse	Hockley	1948	San Andres	4620
19.	Lutrick	Hale	1948	Cisco	8000
20.	Ropes	Hockley	1950	Cisco	9325
21.	J Y	King	1950	Strawn	4220
22.	East Bateman Ranch	King	1950	Strawn	5310
23.	Bledsoe	Cochran	1951	San Andres	4850
24.	Tom "B"	King	1951	Canyon	5430

* Refers to field number on map, Fig. 2.

the fields farther to the South (Fig. 2).

Completion of the Standard of Texas No. 1 Adams, Floyd County, in Strawn reef gave impetus to leasing in that area in 1952. Discovery of San Andres production within the townsite of Littlefield, Lamb County, late in 1953 has increased activity in that area and is to be considered an important discovery as it is the first production north of the Matador arch.

Recent completions in Pennsylvanian reef in east-central Hockley County and a Clear Fork completion in southeastern Lamb County have been other incentives for increased exploration in the area.

Wildcat wells drilled during 1953 totaled 62 in the 2 tiers of counties bordering the Matador arch. Seven were completed as producers. Fig. 3 indicates wildcat wells completed as producers in 1952, 1953, and during the first 6 months of 1954. Data concerning producing fields in the area delimited above are listed in Table 1 and are indicated on the map, Fig. 2. In general the discussion of this paper will be limited to area delimited above.

Stratigraphy

Overlying the Precambrian basement complex in the area, rocks representing all the periods of the Paleozoic may be encountered in the subsurface. A representative electric log is included as Fig. 4 to show the character of the most important portion of the geologic section of the area. Fig. 5 is a typical reflection seismogram obtained in the area. Table 3 is a generalized geologic columnar section of the area.

Precambrian. A considerable range of igneous rock types has been identified in the area where the basement has been penetrated. The following represents the major types: granite (pink, hornblende variety the most common), rhyolite, rhyolite porphyry, andesite, porphyry, quartz diorite, diabase, and basalt. Volcanic tuff and breccia have also been encountered in several wells. Argillaceous siltstones and dolomites have been found intercalated with the extrusive types of igneous rocks. Various varieties of schist and gneiss are the most prevalent metamorphic rock types.

Recent work of Flawn[4] has established several entities of the Precambrian of West Texas. Most of the 12 county area under discussion is underlain by what Flawn describes as the "Panhandle volcanic terrane." In this terrane the basement cratonic rocks have been covered in places with acidic flows intercalated with volcanic tuffs.

In the Palo Duro basin portion of the area basic rocks are encountered in the Precambrian that are, according to Flawn, younger than the rocks of the Panhandle volcanic terrane. They are chiefly gabbroic and diabasic, and probably occur as sill-like or sheet-like masses that penetrate the older acidic extrusives. This area had been designated by Flawn as the "Swisher gabbroic terrane."

The Author

William C. Hayes is a consulting geologist in Lubbock, Texas. He has BS (Drury College), MS (Missouri School of Mines and Metallurgy), and a PhD (Iowa State University) in geology. Before becoming a consultant Hayes worked as a geologist for Consolidated Coppermines Corporation, the North Carolina State Department of Natural Resources, and the Missouri Geological Survey and Water Resources. He was also a member of the geology faculty of North Carolina State College, Iowa State University, and Texas Technological College. Hayes is president of the Lubbock Geological Society and is a member of several other societies.

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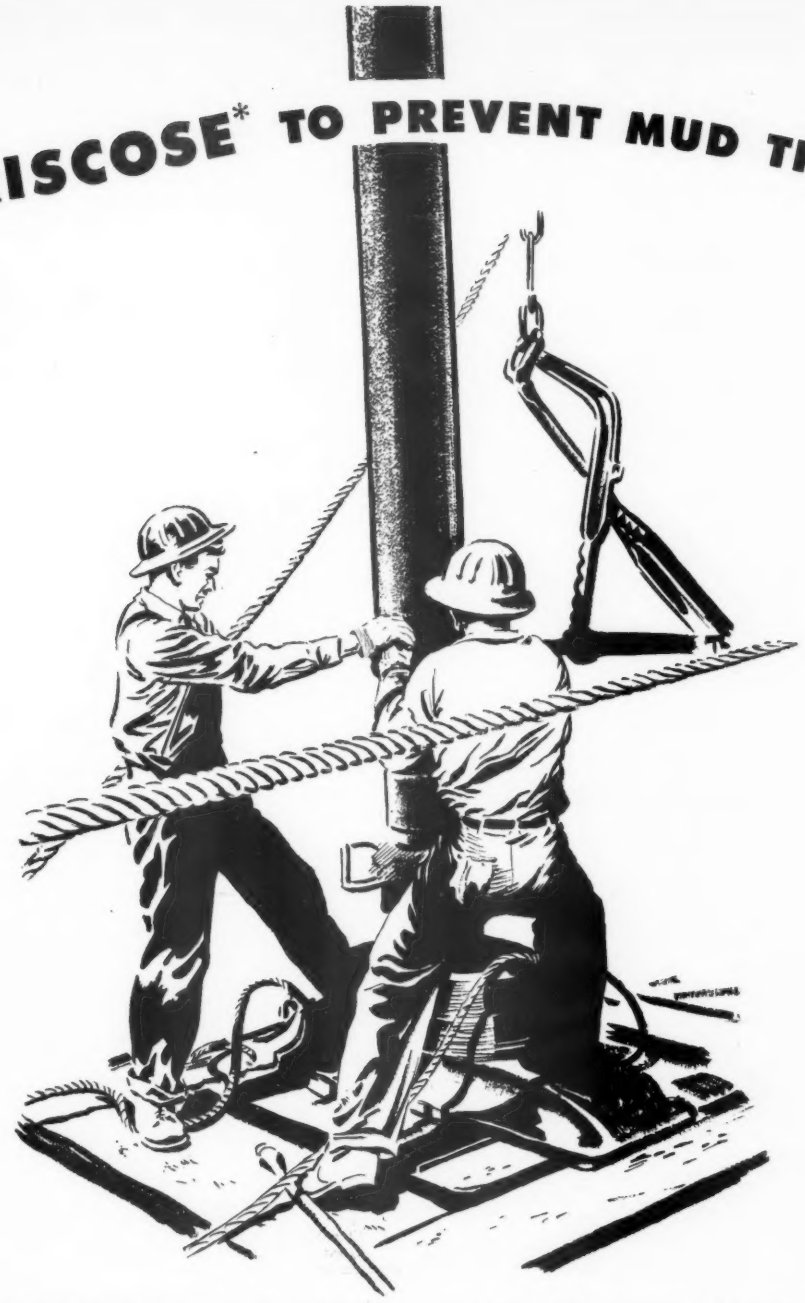

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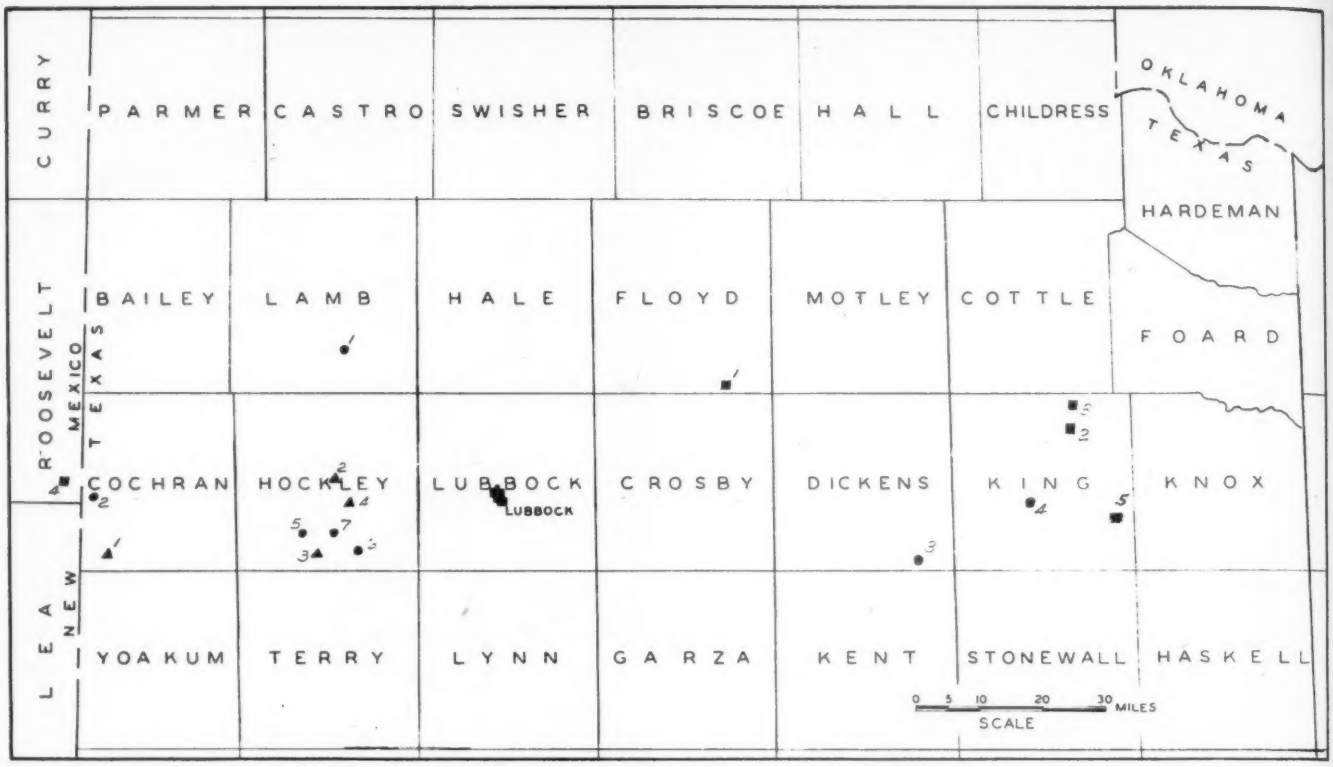

FIG. 3. Wildcat completions in the Matador Arch area—1952, 1953, and January to June, 1954.

TABLE 2.

County	Field Name	Prod. Horiz.	Company	Well Name
Discoveries in 1952 ■				
1. Floyd	Floydada-Penn.	Strawn	Standard of Texas	No. 1 Adams
2. King	Tom "B" Upper Canyon	Canyon	Ard Drilling Company el. al.	No. 1 Masterson
3. King	Tom "B" Bunger sand	Canyon	Ard Drilling Company	No. 14 Masterson
4. Roosevelt	Bluit-San Andres	San Andres	Austral Oil Company	No. 1 McGrail
5. King	Buzzard Peak-Caddo	Canyon	Continental Oil Company	No. 1 Ross
Discoveries in 1953 ●				
1. Lamb	Littlefield-San Andres	San Andres	Texas Company	No. 1 Union Whse.
2. Cochran	Two-States San Andres	San Andres	Leland Fikes, et. al.	No. 1 Evans
3. Dickens	Girard-Tannehill sand	Leonard	Pacific Western Oil Company	No. 1 Smith
4. King	Tapp-Strawn	Strawn	Shell Oil Company	No. 2-1 Burnett est.
5. Hockley	Mallet-Clear Fork	Clear Fork	Bankline Oil and Gas Company and Mid-West Oil Company	No. 2-1 Mallet Ranch
6. Hockley	Ropes West-Penn.	Canyon	Stanolind Oil and Gas	No. 1 Thompson
7. Hockley	Clauene-San Andres	San Andres	Zephyr Drilling Company and Sunray Oil Corporation	No. 1 Pace
Discovieries January to July 1954 ▲				
1. Cochran	unnamed	Dev. s.	Stanolind Oil and Gas	No. 1-D Reed
2. Hockley	Hoblitzelle-Wolfcamp	Wolfcamp	Great Western Drilling and Karl Hoblitzelle	No. 1 Hines
3. Hockley	DLS-Clear Fork	Clear Fork	Stanolind Oil and Gas	No. 1 Slaughter
4. Hockley	Hoblitzelle-Strawn	Strawn	Great Western Drilling and Karl Hoblitzelle	No. 1 Davis

The highest elevation at which the Precambrian is known to occur is in southwestern Cottle County, the lowest elevation known in the area is in the northwestern portion of Lubbock County. The resulting maximum relief is approximately 5600 ft.

Present relief on top of the Precambrian is presented in Fig. 7. Subsea elevations were computed on the top of essentially unweathered basement; or where drilling was stopped in the overlying "granite wash" above the basement, the TD of the hole was used.

Paleozoic

Cambrian. The oldest sediments of Paleozoic age are to be found in the eastern portion of the area in King and Cottle counties. Lithologic logs of several wells in these counties indicate the presence of Cambrian sediments.

It is difficult to assign these sediments to any of the known Cambrian formations. Their lithology is quite similar to the Hickory member of the Riley formation which is present in wells to the south. In Nolan County—approximately 60 miles to the south—definite Hickory sandstone is present but to date definite correlation with the Cambrian sediments to the north has not been established.

Where the Cambrian crops out in the Llano area of Central Texas the beds are fossiliferous but fossil data from cores and well cuttings are lacking. At the outcrop linguloid brachiopods, trilobites, and fossils resembling crinoid columnals (perhaps cystoid columnals?) are plentiful in several members. But to the unfossiliferous character in the subsurface and the clastic nature of the sediments, correlation is extremely difficult. It is thought that a detailed petrographic study may aid in future correlations.

A considerable number of sample logs from wells in King and Cottle counties distinguish either Wilberns or Hickory. Majority of these wells were logged several years ago and the formations or members then designated probably do not represent present day interpretations. Recent production from the Cambrian in Coke and Nolan counties has strongly pointed out the importance of Cambrian rocks as reservoirs.

The general lithology of the Hickory is quite distinctive as it is predominately a very coarse grained, subangular sandstone with considerable hematitic cementing material. The overlying Wilberns may contain a combination of the following members: Fine grained, glauconitic sandstone; green glauconitic shale, and thin bedded dolomite with subordinate thin lime-

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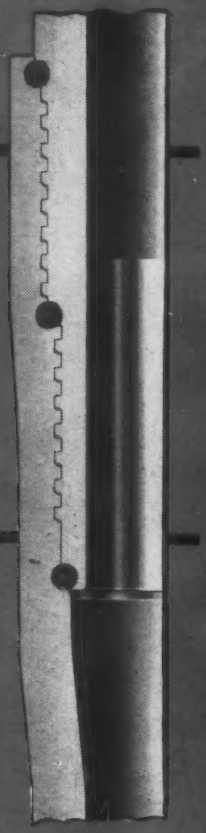

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5 —15# J-55	8,850	10,720	287
5 —15# N-80	11,590	12,250	328
5 —18# N-80	15,200	13,040	421
5½—14# J-55	5,640	9,900	244
5½—15.5# J-55	6,860	10,420	288
5½—17# J-55	8,000	10,870	330
5½—17# N-80	10,470	12,380	376
5½—20# N-80	13,480	13,100	467
6⅝—20# J-55	5,440	10,260	360
6⅝—24# J-55	7,560	11,100	471
6⅝—24# N-80	9,870	12,670	538
6⅝—28# N-80	12,640	13,320	663
7 —20# J-55	4,440	10,000	352
7 —23# J-55	5,850	10,700	436
7 —23# N-80	7,640	12,200	497
7 —26# J-55	7,220	11,210	518
7 —26# N-80	9,460	12,800	591
7 —29# N-80	11,320	13,250	685
7⅝—26.4# J-55	5,350	10,850	499
7⅝—26.4# N-80	6,990	12,370	569
7⅝—29.7# N-80	8,730	12,950	677
7⅝—33.7# N-80	10,790	13,100	779
8⅝—32# J-55	4,870	10,090	565
8⅝—36# J-55	6,080	10,650	674
8⅝—36# N-80	7,950	12,160	769
8⅝—40# N-80	9,580	12,680	897
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9⅝—40# J-55	4,920	10,610	744
9⅝—40# N-80	6,280	12,130	850
9⅝—43.5# N-80	7,610	12,570	966
9⅝—47# N-80	8,710	12,910	1072

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stone layers. The Cambrian sediments may attain a maximum thickness of approximately 300 ft near the eastern portion of the area.

Several geologists have expressed the thought that the "granite wash" that directly overlies the basement may be of Cambrian age. If so, the maximum thickness would be in the order of 1000 ft. The Humble Oil and Refining Company's No. 1 Hobgood well in northern Hockley County penetrated 1010 ft of such "granite wash."

Ordovician. The Lower Ordovician is represented in the area by the Ellenburger.[1] It is generally a light colored cherty dolomite, in places lithographic and containing green shale partings. Several characteristic types of chert may be distinguished, the oolitic varieties being the most conspicuous. Sand grains that exhibit rounded and frosted surfaces occur scattered sporadically throughout the Ellenburger.

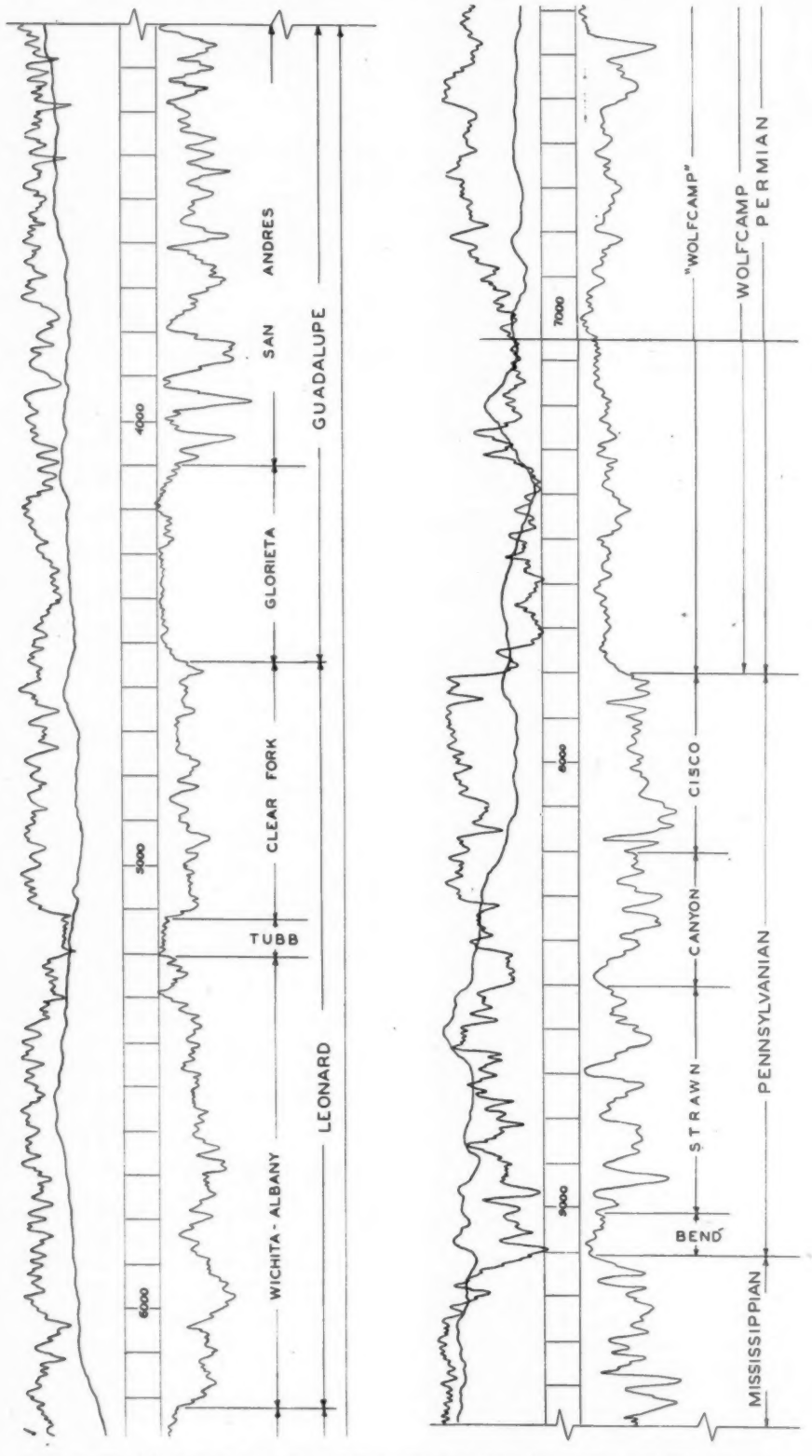

FIG. 4. Electric log of a portion of Tobe Foster's Number 1 Harrell, Hale County.

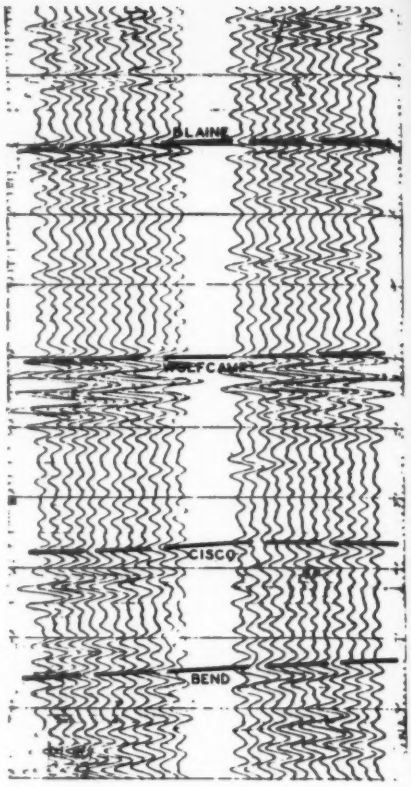

FIG. 5. A typical reflection seismograph obtained in the Matador Arch area.

Subdivision of the Ellenburger on the basis of insoluble residues have been attempted by the majority of interested oil companies. Published reports by Cole[3] and Cloud and Barnes[2] include data on subdivisions of the Ellenburger.

At the outcrop in the Llano area the Ellenburger is approximately 1825 ft thick, and may attain a thickness of about 3000 ft in the area under discussion. The Ellenburger wedge-out is indicated on the accompanying map, Fig. 7. It appears to have been truncated with the lower formations being closer to the Precambrian highs. A similar truncation is reported to occur on both the north and south sides of the Electra arch.

It is thought that Ellenburger is present north of the Matador arch only as far north as Castro County at the western end of the area, but it appears to be continuous over the major portion of the eastern part of the area. It is not present over several of the Precambrian highs, but these small areas have not been indicated on the map.

Because of the great similarity of lithology of the Ellenburger as it is traced northward to the overlying Montoya and Fusselman the presence of Ellenburger north of the Matador arch has long been debated. Its presence is now generally recognized.

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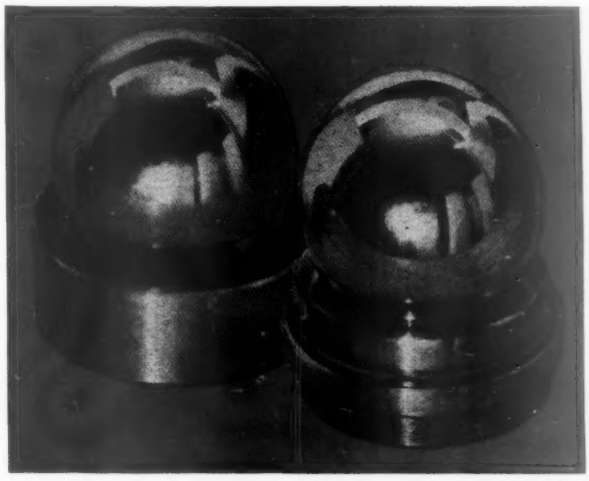

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TABLE 3. Generalized geologic columnar section.

Era	Period	Series	Group	Thickness*	Important Units
Cenozoic	Tertiary	Pliocene	Ogallala	0–400	
Mesozoic	Cretaceous	Gulf	"Cretaceous"	0–200	
		Commanche			
	Triassic		Dockum	700	
Paleozoic	Permian	Ochoa		1200	
		Guadulupe	Whitehorse	700	
			San Andres	1500	Glorieta
		Leonard		1800	Clear Fork Tubb Wichita-Albany
		Wolfcamp		1600	
	Pennsylvanian	Virgil	Cisco	0–1250	
		Missouri	Canyon	0–1500	
		Desmoines	Strawn	0–1400	
		Atoka	Bend	0–600	
	Mississippian	Chester		0–175	
		Meramec		0–150	
		Osage		0–200	
		Kinderhook		0–150	
					<(?) Woodford
	Devonian			0–75	Devonian limestone
	Silurian		Hunton	0–300	Fusselman
	Ordovician	Canadian	Ellenburger	0–400	Montoya
	Cambrian			0 (?)–1000 (?)	Wilberns (?) Hickory (?) Granite wash (?)
Precambrian					Basic volcanics Acidic volcanics Metamorphics

*Approximate maximum thickness.

The Middle Ordovician Simpson wedges-out south of the area in Yoakum County. It may be present locally (as filling low areas in the Ellenburger) farther north and east.

Upper Ordovician is represented by the Montoya formation. In the area it is dolomitic although farther south in the Midland basin it is represented by approximately 400 ft of limestone. Typically it is a light brown argillaceous dolomite with subordinate chert. It is believed that the Montoya is not present north of the Matador arch and its eastern wedge-out in the area is to the east of the wedge-out of the overlying Fusselman. This would appear to be evidence for off-lap, but farther south definite transgressive on-lap relationships are reported.

Silurian. The Silurian limestone of the Permian basin is now correlated with the lower Hunton terrane of Oklahoma and is named the Fusselman limestone; the overlying shale is designated only as the "Silurian shale." Ostracods, graptolites, and corals indicate an upper Niagaran age for the majority of the Fusselman.

In the northern portion of the Midland basin, south of the Matador arch, the Fusselman is dolomitic resembling to an appreciable extent the underlying Montoya and the dolomitic members of the overlying Devonian. The lower portion may contain 20-25 per cent chert. The northern limit is essentially coincident with the trend of the Matador arch and the eastern limit is in Hockley and Lynn counties.

Devonian. Definite Devonian strata in the area, consisting of cherty dolo-

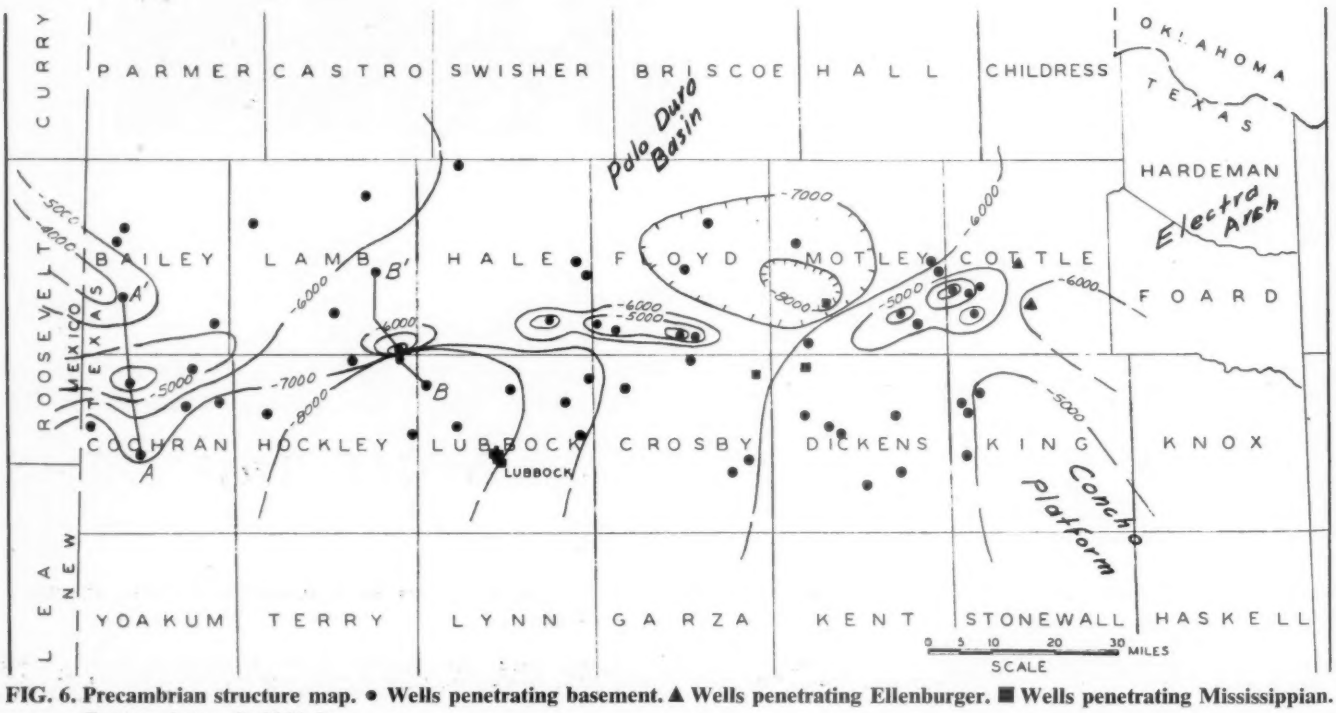

FIG. 6. Precambrian structure map. • Wells penetrating basement. ▲ Wells penetrating Ellenburger. ■ Wells penetrating Mississippian. Contour interval: 1000 ft.

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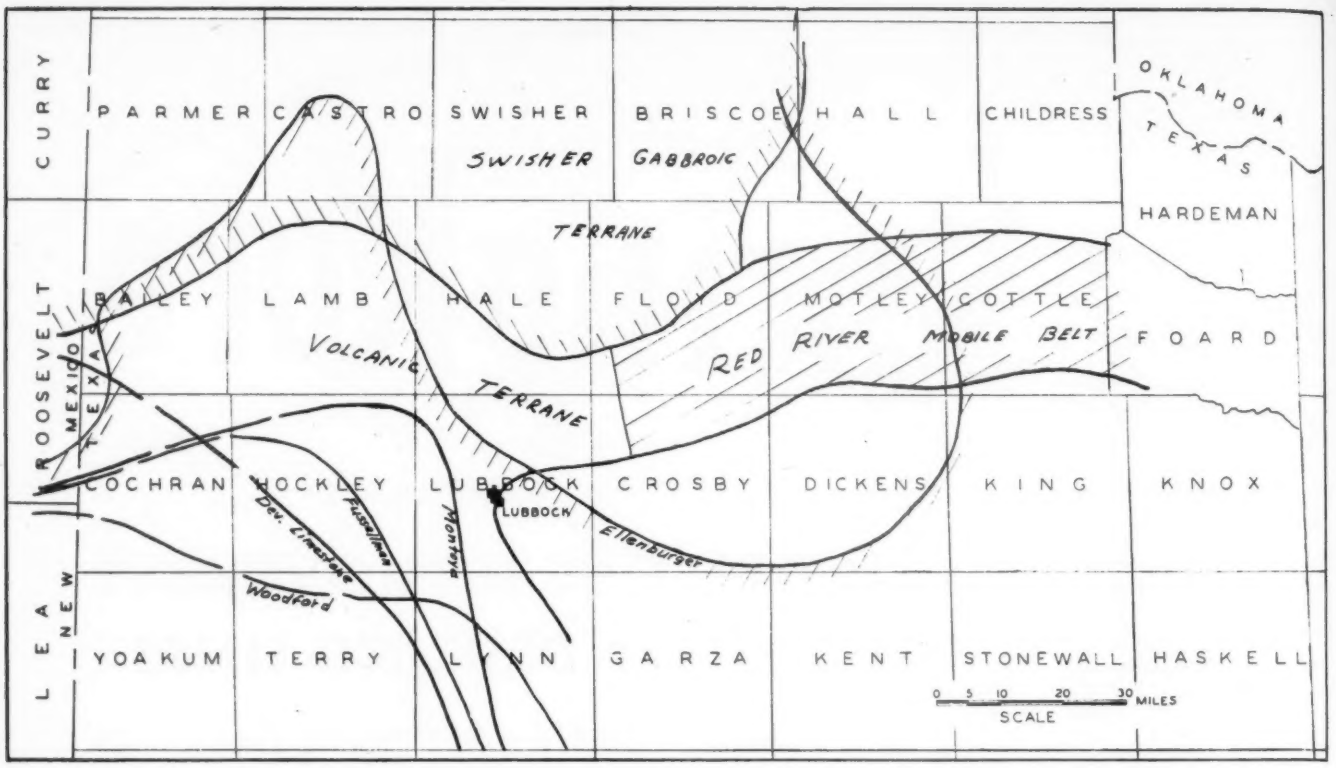

FIG. 7. Composite subsurface geologic map (Precambrian modified after Flawn).

mitic limestones have been called the "Devonian limestone." Above this carbonate section is the Woodford shale. In the Midland basin the Woodford is glauconitic, cherty, pyritiferous, dark brown to black shale containing several layers of dark colored argillaceous dolomite.

The portion of the Woodford found south of the Matador arch in Yoakum, Terry, and Lynn counties is generally represented by a black shale containing a basal argillaceous sandstone in places.

By many the Woodford is considered Devonian, and by others it is thought to be Mississippian. It might be compared to the Chattanooga shale of the Mississippi Valley area in that it may represent late Devonian and early Mississippian sedimentation.

Although the underlying Devonian limestone, Fusselman, and Montoya exhibit off-lap relations south of the arch, the Woodford appears to truncate then in the Lynn County area. This structural relationship would favor a Mississippian age for the Woodford.

Mississippian. Approximately 100 miles south of the Matador arch a thickness of 1100 ft of siliceous limestone of Mississippian age has been encountered. In the Permian Basin the indecisive term "Mississippian limestone" has been used previously for the now defined Osage portion of the Mississippian. At present Kinderhook, Osage, Meramec, and Chester are recognized in the area.

The lowermost unit—probably equivalent to the Kinderhook of the Upper Mississippian Valley—consists mainly of greenish-gray or light brown limestone containing crinoidal material, chert, and gray and green shale. It may range in thickness from 75 to 150 ft.

The Osage is represented by approximately 200 ft of crinoidal crystalline limestone with light gray to blue chert. The Meramec is represented by about 150 ft of limestone, some chert and crinoidal material. Approximately 170 ft of light brown oolitic limestone has been assigned to the Chester. It contains considerable quantities of gray and green shale and fine grained sand.

Some dolomite is present in the Mississippian in local areas near the highs of the Matador structure. Some geologists have expressed the thought that dolomitization occurred in these areas in post-Mississippian time during the major movement along the trend of the Matador arch. In the Palo Duro basin Meramec and Osage sediments directly overlay the Precambrian.

Pennsylvanian. Pennsylvanian sediments of the area have been assigned to the Bend, Strawn, Canyon, and Cisco series; equivalents of the Atakon, Desmoinesian, Missourian, and Virgilian of the Upper Mississippian Valley. Some of the most interesting and challenging studies in the area are those of the Pennsylvanian stratigraphy and paleogeology. Since the discovery of the Scurry County reef considerable impetus was given to the study of Pennsylvanian reef problems in West Texas and eastern New Mexico.

Three characteristic types of sediments are represented by the Pennsylvanian: The basin section of dark shales; the shelf section of limestone, few shales and some evaporites, and the reef accumulations.

Where the Bend is present it may be identified by its arenaceous and arkosic character. It may be present up to a thickness of 600 ft, but usually around 300 ft may be expected.

The thickness of Strawn, Canyon, and Cisco will range to a considerable extent dependent upon whether basin or shelf sections are encountered. The Strawn generally consists of crystalline limestone whereas the Canyon is usually dark gray micaceous shale and the Cisco a black shale where they are in non-reef areas.

The base of the Pennsylvanian is easily recognized—either by the presence of Bend sandstone or the presence of the underlying cherty limestone or dolomites. The top is difficult to determine particularly in the basin sections. The basin shales of Cisco age appear to have the same lithologic features as the overlying Wolfcamp shales. In the areas where reef build-up continued into Permian time the reef lithology continues into the Wolfcamp and no lithologic break is present between the system boundaries.

It has been common practice to call the "top of Pennsylvanian lime" rather than the top of the Cisco. The identifi-

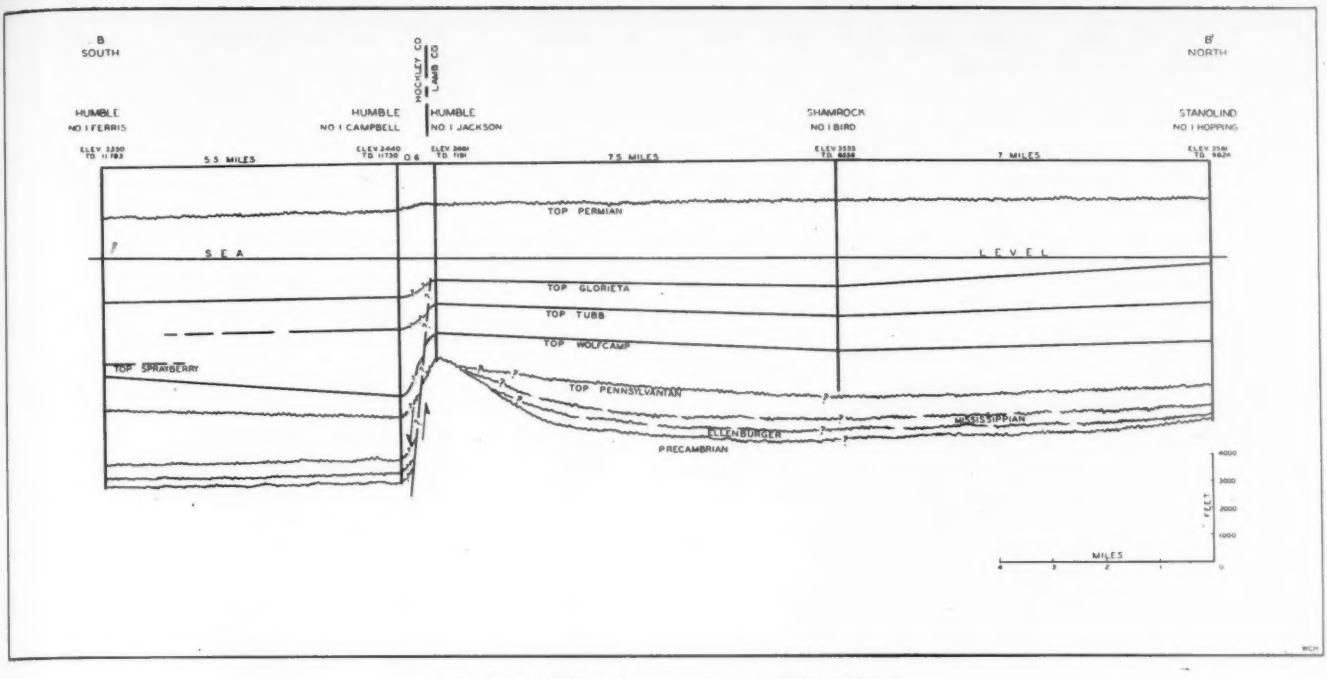

FIG. 8. North-South cross section B-B′, Fig. 6.

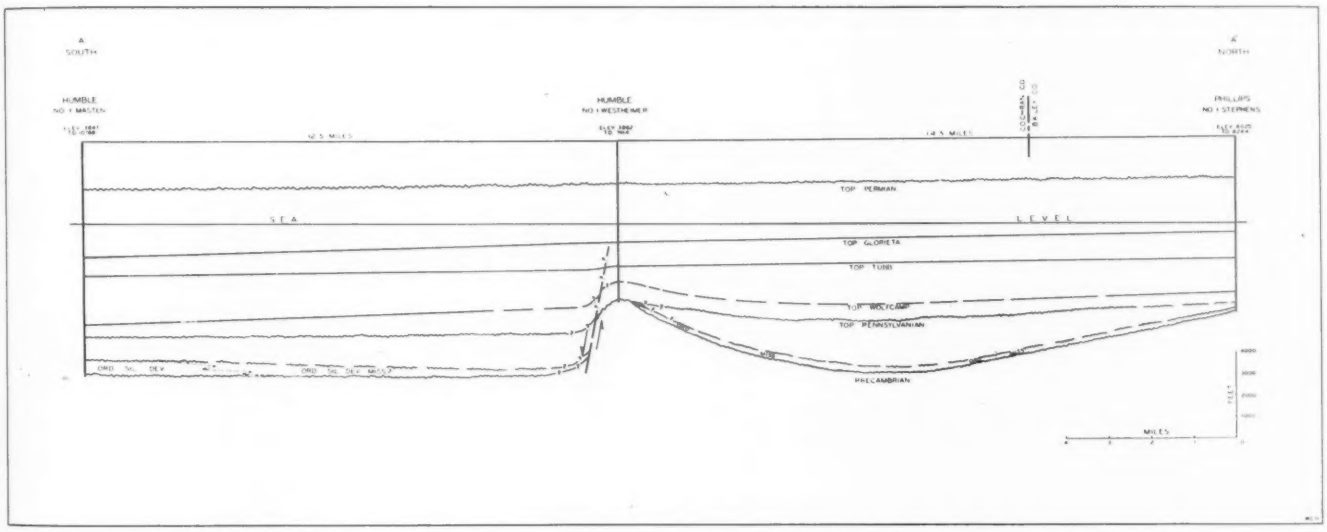

FIG. 9. North-South cross section A-A′. Fig. 6.

cation of the top of the Pennsylvanian is largely dependent upon paleontologic data, and one is fortunate if it may be placed within 50 ft in many instances.

The thickest section of Pennsylvanian sediments occurs in the Palo Duro basin where a maximum of 4500 ft has been drilled.

It has generally been thought that Pennsylvanian sediments were absent over the crest of many of the Precambrian highs but recent paleontological data indicate that there is a strong possibility that thin sections of Strawn, Canyon, and Cisco sediments may be present on the highs.

Permian. Sediments of the Wolfcamp, Leonard, Guadalupe, and Ochoa series are present in the area. Approximately 1600 ft of gray and brown shales with numerous limestone and dolomite layers constitute the Wolfcamp. It thickens southward to over 5000 ft of clastics in Pecos County and thickens regionally westward in contrast with the Pennsylvanian. Reef type limestone is found in places where reef build-up persisted through the Cisco into the Wolfcamp. The Dean—an excellent sandstone marker horizon in the Midland basin—does not extend as far north as the Matador arch.

In southeastern New Mexico lagoonal facies of the Leonard, Guadalupe, and Ochoa are recognized. In the Matador area and to the east these sediments appear as shelf type facies and gradually merge into the lagoonal facies westward.

The Leonard series is conveniently divided into the lower and upper. The lower portion consists of the famous Spraberry of the Midland basin. In eastern New Mexico its equivalent is the Abo, consisting of red shale, sandstone, and arkosic material. In the local area this portion has generally been called the Wichita-Albany and consists of approximately 1000 ft of dark shales (in the basin sections) becoming lighter and more red in color in the shelf areas.

The upper portion of the Leonard, or the Clear Fork, has been an important producing horizon in the area and consists of approximately 750 ft of red shales, anhydrite, and salt. The "Tubb" sand near the base of the Clear Fork is an excellent marker in the subsurface either on lithologic or electric logs. This upper portion has not been named in the Midland basin but the lagoonal facies in eastern New Mexico is the Yeso.

Approximately 400 ft of gray, fine grained, sandy dolomite that becomes

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more sandy westward forms the lower portion of the Guadalupe and had been named the Glorieta. The Glorieta is the lowest unit in the somewhat loosely defined San Andres and is at least a partial equivalent to the San Angelo to the east. The upper portion of the San Andres, or the San Andres (restricted), consists of about 1100 ft of fine grained crystalline dolomite. It bebecomes finer grained and contains a greater percentage of anhydrite and fine clastics westward into New Mexico.

The upper portion of the Guadalupe is named the Whitehorse group and consists of alternating layers of dolomite, sandstone, shale, and limestone. Northward and westward the clastic ratio increases as does the percentage of evaporites. The Yates, a reddish gray sandstone and shale, contains frosted quartz grains and is an important and readily recognized marker horizon.

The Ochoa consists largely of evaporites (anhydrite and salt), red shales, and minor dolomite layers. It is customary to call the "top of the anhydrite" rather than the top of the Permian, as the first anhydrite encountered may be as much as 150 ft below the top of the Permian. The Ochoa is represented by approximately 900 ft of sediments.

Post-Paleozoic. Triassic redbeds occur above the Permian throughout the area and consist of red shales, siltstones, and fine grained sandstones which may attain a thickness of around 700 ft. They have been divided into Tecovas, Santa Rosa, and Chinle formations of the Dockum group.

No Jurassic sediments are known in the area.

Lower Cretaceous sediments consist of sandstone, limestone, and shale that overlie the Triassic from southern Bailey County southeastward. Cretaceous rocks crop out around the edges of shallow playa basins in Lynn, Lubbock, Lamb, and Bailey counties.

The Ogallala of Pliocene age blankets the southern high plains with up to 700 ft of poorly consolidated sands, clays, and gravels. This portion of the Ogallala is perhaps the largest individual underground aquifer known today. It supplies irrigation water to an area that extends from Amarillo south to Dawson County and from the cap rock in Floyd and Crosby counties west into New Mexico. Caliche deposits are numerous within the Ogallala and form the cap rock on the eastern and western edges of the high plains.

Conclusion

Interpretations of the geologic history and structural relationships of the Matador arch have been discussed, at least briefly, for some time but no comprehensive work has been published on the area.

One situation that has hindered such a study is that district boundaries of numerous oil companies have been the county lines that are roughly coincident with the Matador arch. This is particularly noticeable in the terminology of Permian sediments. North of the arch the North-Central Texas terms are in vogue, whereas south of the arch Permian basin terminology is used. As we know, it has been difficult to give proper attention to fringe areas of a district.

A confusing item has been the terminology relating to the structure itself; that is whether one is referring to the Precambrian, early Paleozoic, or late Paleozoic structural features. If one is referring to the Precambrian, the Matador is a series of peaks or a range of mountains; if early Paleozoic time is indicated, perhaps it might be called an archipelago; and if one is referring to the late Paleozoic the structure represented is a broad warp or flexure.

Along the trend of the Matador arch there are no wells penetrating the basement lows indicated on the map, Fig. 6. That such lows are present is highly suggested by the attitude of upper Pennsylvanian and Permian sediments in the area and by interpretative geophysical data. Not only are the dips reversed on the north and south of the structure but peripheral dips of the Permian are encountered in several area along the trend of the structure.

Many geologists concur with the idea that the structure may be dated as early Pennsylvanian, probably Bendian. The writer believes, however, that it had its conception and was a definable structural unit in late Precambrian time although admitting the major movement now apparent (amounting to a displacement of at least 2500 ft) may have occurred during the late Paleozoic.

From regional studies it is quite noticeable that the area of "no Ellenburger" is roughly equivalent to the area that Flawn had designated the Swisher gabbro terrane plus the eastern portion of the Matador arch (Fig. 7). This parallelism does not agree in the area of the northernmost extension of the Ellenburger in the western part of the area in Castro County and in the southeastern area of "no Ellenburger." The boundaries do suggest, however, that there is a relationship between the area underlain by the Swisher gabbro terrane and the area where the Ellenburger is absent. Perhaps the controlling factor may have been the presence of a land mass of low relief formed by the basic extrusions which constitute the gabbro terrane.

Another somewhat fortuitous relationship exists—if one postulates movement in Bendian time — where the wedge-out limits of the Montoya, Fusselman, and Woodford are found to bend westward roughly paralleling the trend of the structure. Devionian limestone has been recognized north of the arch in Bailey County but farther westward its wedge-out bends southward to a position roughly coincident with the Matador arch trend.

Although a great deal has been learned about the area during the past 10 years, many problems remain unsolved and have been approached only by interpretative studies. Oil shows in the Palo Duro basin have kept interest alive in that area and the sparse well control has condemned only a minute portion of the area. Many detailed geologic studies are in progress attempting to solve a number of the unanswered questions and, I am sure, the result will point the way for further exploration programs in the Matador arch area.

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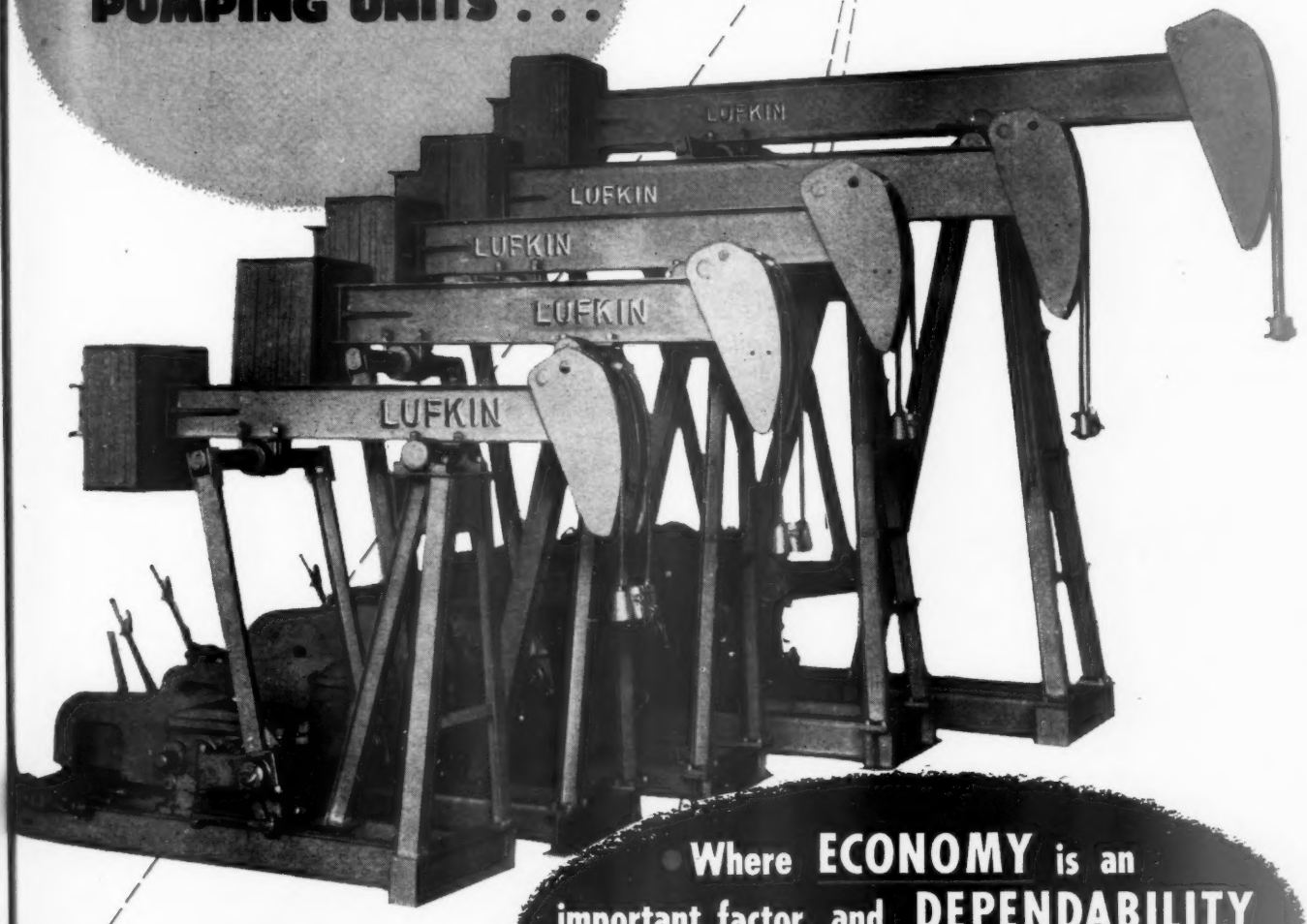

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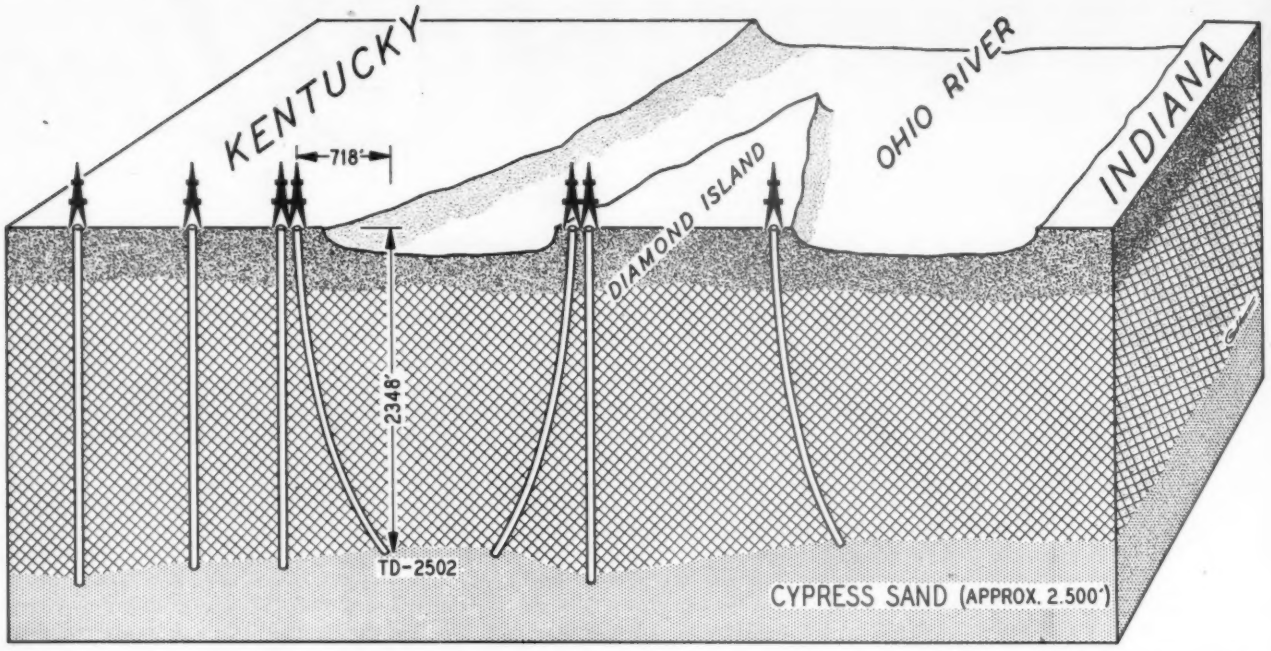

FIG. 1. Diagram shows development of the North Smith Mills pool of Kentucky. Three holes have been drilled directionally under the river from the Kentucky shore, and four drilled directionally from Diamond Island northward towards Indiana.

"Off-Shore" Wells on the Ohio River

. . . mark Carter Diamond Island area production

A. M. ROWLEY*

THE Carter Oil Company is obtaining good crude oil production from beneath the bed of the Ohio River through directional drilling from the Kentucky shore and from an island in the middle of the river.

As far as is known, this is the first time crude oil production has been obtained from under a large, navigable river through directional drilling.

Operation is being carried on in the North Smith Mills pool of Kentucky, near Henderson, and about 15 miles southwest of Evansville, Indiana. Carter has 21 producing oil wells in the pool and one dry hole. Of the producers, 7 are directionally drilled holes, 3 from the Kentucky shore and 4 from Diamond Island, in the middle of the river and north from wells on the Kentucky shore. All 7 are bottomed under the river.

The wells are capable of producing between 250 and 300 bbl of 35 to 36 gravity oil per day and are on the pump. Wells on the Kentucky shore are connected to the pipe line gathering system in the pool. Production from wells on the island is barged to the Kentucky shore and picked up there by the pipe line gathering system.

The oil-bearing horizon, called the Cypress sand, is found at a depth of generally 2500 ft, less in some places under the Ohio River bed. It extends under the river bed north from the Kentucky shore, also under Diamond Island, and to the north, under the river bed between the island and the Indiana shore.

One of Carter's directional wells was drilled on the north shore of the island and curved towards the Indiana shore and bottomed under the river bed between the island and the Indiana shore. It was a producer with an average daily output about the same as the other wells drilled in the pool.

Carter started its drilling campaign in the pool late last year. Its first well

*Oil writer for the Tulsa Tribune, Tulsa, Oklahoma.

EXCLUSIVE

FIG. 2. Typical sub-structure on Diamond Island. This one is 27 ft high— believed to be the highest operated by Carter Oil Company.

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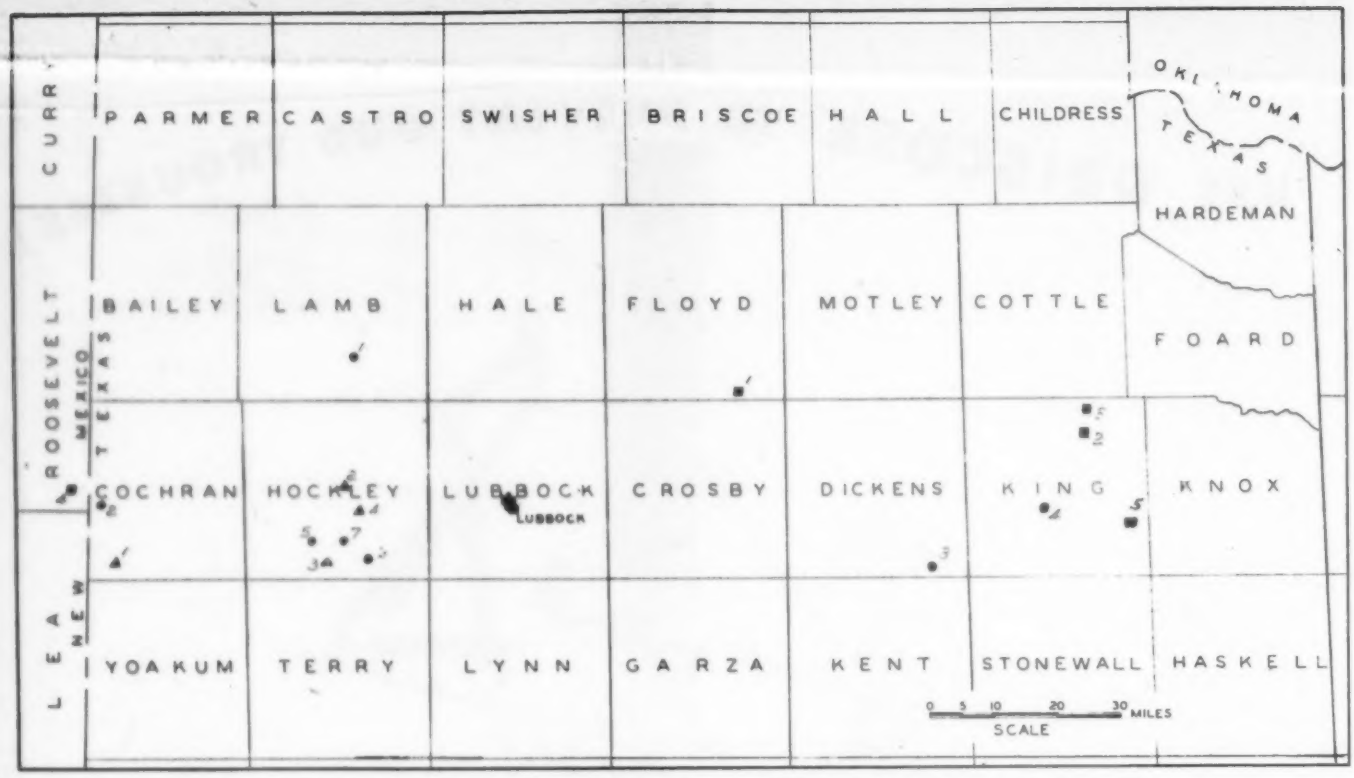

FIG. 3. Wildcat completions in the Matador Arch area—1952, 1953, and January to June, 1954.

TABLE 2.

County	Field Name	Prod. Horiz.	Company	Well Name
Discoveries in 1952				
1. Floyd	Floydada-Penn.	Strawn	Standard of Texas	No. 1 Adams
2. King	Tom "B" Upper Canyon	Canyon	Ard Drilling Company el. al.	No. 1 Masterson
3. King	Tom "B" Bunger sand	Canyon	Ard Drilling Company	No. 14 Masterson
4. Roosevelt	Bluit-San Andres	San Andres	Austral Oil Company	No. 1 McGrail
5. King	Buzzard Peak-Caddo	Canyon	Continental Oil Company	No. 1 Ross
Discoveries in 1953				
1. Lamb	Littlefield-San Andres	San Andres	Texas Company	No. 1 Union Whse.
2. Cochran	Two-States San Andres	San Andres	Leland Fikes, et. al.	No. 1 Evans
3. Dickens	Girard-Tannehill sand	Leonard	Pacific Western Oil Company	No. 1 Smith
4. King	Tapp-Strawn	Strawn	Shell Oil Company	No. 2-1 Burnett est.
5. Hockley	Mallet-Clear Fork	Clear Fork	Bankline Oil and Gas Company and Mid-West Oil Company	No. 2-1 Mallet Ranch
6. Hockley	Ropes West-Penn.	Canyon	Stanolind Oil and Gas	No. 1 Thompson
7. Hockley	Clauene-San Andres	San Andres	Zephyr Drilling Company and Sunray Oil Corporation	No. 1 Pace
Discoveries January to July 1954				
1. Cochran	unnamed	Devl s.	Stanolind Oil and Gas	No. 1-D Reed
2. Hockley	Hoblitzelle-Wolfcamp	Wolfcamp	Great Western Drilling and Karl Hoblitzelle	No. 1 Hines
3. Hockley	DLS-Clear Fork	Clear Fork	Stanolind Oil and Gas	No. 1 Slaughter
4. Hockley	Hoblitzelle-Strawn	Strawn	Great Western Drilling and Karl Hoblitzelle	No. 1 Davis

The highest elevation at which the Precambrian is known to occur is in southwestern Cottle County, the lowest elevation known in the area is in the northwestern portion of Lubbock County. The resulting maximum relief is approximately 5600 ft.

Present relief on top of the Precambrian is presented in Fig. 7. Subsea elevations were computed on the top of essentially unweathered basement; or where drilling was stopped in the overlying "granite wash" above the basement, the TD of the hole was used.

Paleozoic

Cambrian. The oldest sediments of Paleozoic age are to be found in the eastern portion of the area in King and Cottle counties. Lithologic logs of several wells in these counties indicate the presence of Cambrian sediments.

It is difficult to assign these sediments to any of the known Cambrian formations. Their lithology is quite similar to the Hickory member of the Riley formation which is present in wells to the south. In Nolan County—approximately 60 miles to the south—definite Hickory sandstone is present but to date definite correlation with the Cambrian sediments to the north has not been established.

Where the Cambrian crops out in the Llano area of Central Texas the beds are fossiliferous but fossil data from cores and well cuttings are lacking. At the outcrop linguloid brachiopods, trilobites, and fossils resembling crinoid columnals (perhaps cystoid columnals?) are plentiful in several members. But to the unfossiliferous character in the subsurface and the clastic nature of the sediments, correlation is extremely difficult. It is thought that a detailed petrographic study may aid in future correlations.

A considerable number of sample logs from wells in King and Cottle counties distinguish either Wilberns or Hickory. Majority of these wells were logged several years ago and the formations or members then designated probably do not represent present day interpretations. Recent production from the Cambrian in Coke and Nolan counties has strongly pointed out the importance of Cambrian rocks as reservoirs.

The general lithology of the Hickory is quite distinctive as it is predominately a very coarse grained, subangular sandstone with considerable hematitic cementing material. The overlying Wilberns may contain a combination of the following members: Fine grained, glauconitic sandstone; green glauconitic shale, and thin bedded dolomite with subordinate thin lime-

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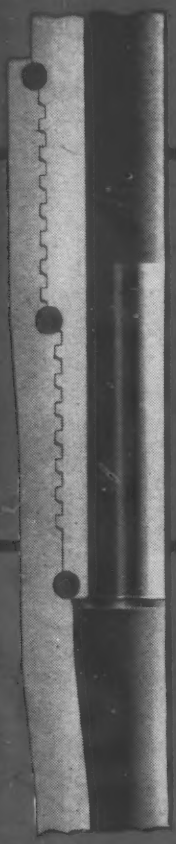

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SIZE WEIGHT & MATERIAL	SETTING DEPTH: COLLAPSE SF = 1⅛	SETTING DEPTH: TENSION SF = 1.8	MINIMUM ULTIMATE JOINT TENSION
	FEET	FEET	1000 LBS.
5 —13# J-55	6,990	10,040	232
5 —15# J-55	8,850	10,720	287
5 —15# N-80	11,590	12,250	328
5 —18# N-80	15,200	13,040	421
5½—14# J-55	5,640	9,900	244
5½—15.5# J-55	6,860	10,420	288
5½—17# J-55	8,000	10,870	330
5½—17# N-80	10,470	12,380	376
5½—20# N-80	13,480	13,100	467
6⅝—20# J-55	5,440	10,260	360
6⅝—24# J-55	7,560	11,100	471
6⅝—24# N-80	9,870	12,670	538
6⅝—28# N-80	12,640	13,320	663
7 —20# J-55	4,440	10,000	352
7 —23# J-55	5,850	10,700	436
7 —23# N-80	7,640	12,200	497
7 —26# J-55	7,220	11,210	518
7 —26# N-80	9,460	12,800	591
7 —29# N-80	11,320	13,250	685
7⅝—26.4# J-55	5,350	10,850	499
7⅝—26.4# N-80	6,990	12,370	569
7⅝—29.7# N-80	8,730	12,950	677
7⅝—33.7# N-80	10,790	13,100	779
8⅝—32# J-55	4,870	10,090	565
8⅝—36# J-55	6,080	10,650	674
8⅝—36# N-80	7,950	12,160	769
8⅝—40# N-80	9,580	12,680	897
9⅝—36# J-55	3,950	10,100	634
9⅝—40# J-55	4,920	10,610	744
9⅝—40# N-80	6,280	12,130	850
9⅝—43.5# N-80	7,610	12,570	966
9⅝—47# N-80	8,710	12,910	1072

Tension strength calculations are based on 55,000 lbs. yield and 92,000 lbs. ultimate for J-55 material, and on 80,000 lbs. yield and 105,000 lbs ultimate for N-80 material.
Information on other sizes available on request.

stone layers. The Cambrian sediments may attain a maximum thickness of approximately 300 ft near the eastern portion of the area.

Several geologists have expressed the thought that the "granite wash" that directly overlies the basement may be of Cambrian age. If so, the maximum thickness would be in the order of 1000 ft. The Humble Oil and Refining Company's No. 1 Hobgood well in northern Hockley County penetrated 1010 ft of such "granite wash."

Ordovician. The Lower Ordovician is represented in the area by the Ellenburger.[1] It is generally a light colored cherty dolomite, in places lithographic and containing green shale partings. Several characteristic types of chert may be distinguished, the oolitic varieties being the most conspicuous. Sand grains that exhibit rounded and frosted surfaces occur scattered sporadically throughout the Ellenburger.

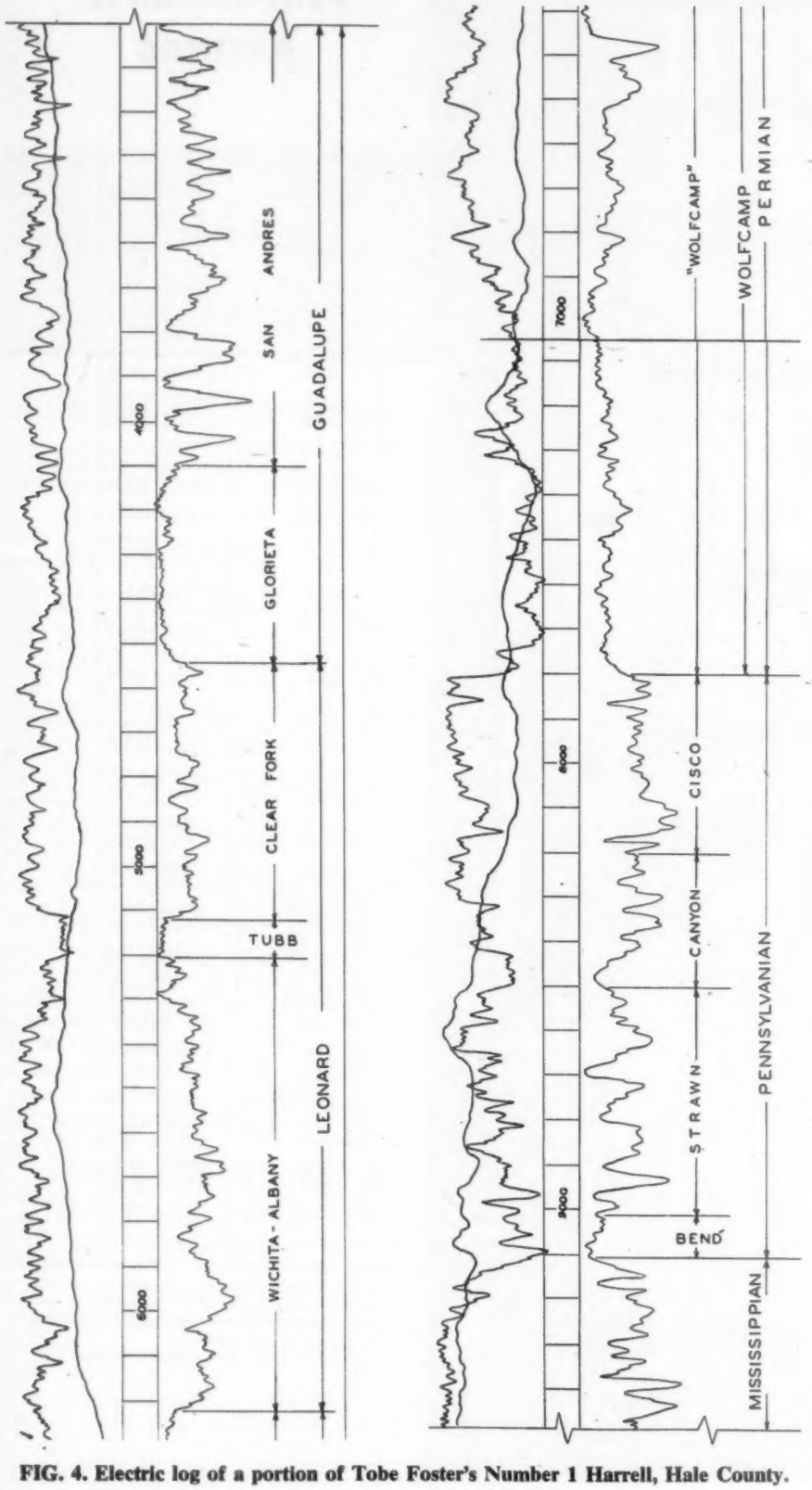

FIG. 4. Electric log of a portion of Tobe Foster's Number 1 Harrell, Hale County.

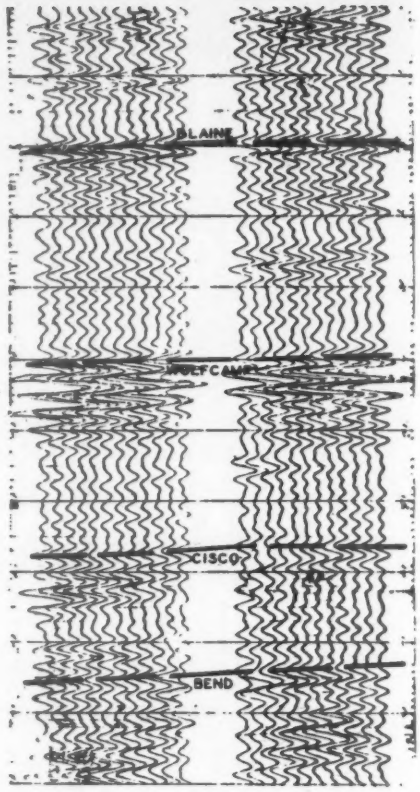

FIG. 5. A typical reflection seismograph obtained in the Matador Arch area.

Subdivision of the Ellenburger on the basis of insoluble residues have been attempted by the majority of interested oil companies. Published reports by Cole[3] and Cloud and Barnes[2] include data on subdivisions of the Ellenburger.

At the outcrop in the Llano area the Ellenburger is approximately 1825 ft thick, and may attain a thickness of about 3000 ft in the area under discussion. The Ellenburger wedge-out is indicated on the accompanying map, Fig. 7. It appears to have been truncated with the lower formations being closer to the Precambrian highs. A similar truncation is reported to occur on both the north and south sides of the Electra arch.

It is thought that Ellenburger is present north of the Matador arch only as far north as Castro County at the western end of the area, but it appears to be continuous over the major portion of the eastern part of the area. It is not present over several of the Precambrian highs, but these small areas have not been indicated on the map.

Because of the great similarity of lithology of the Ellenburger as it is traced northward to the overlying Montoya and Fusselman the presence of Ellenburger north of the Matador arch has long been debated. Its presence is now generally recognized.

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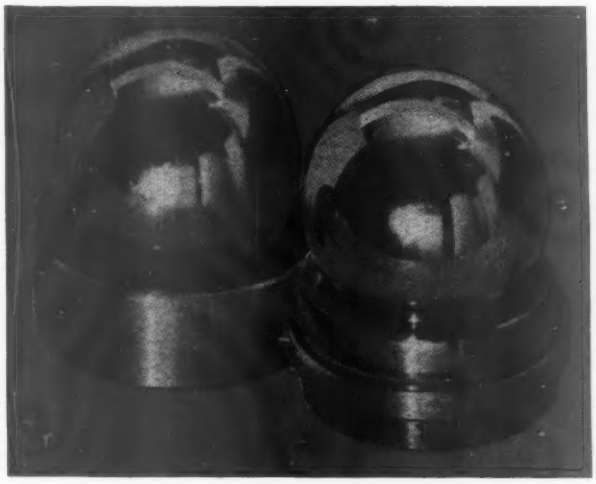

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TABLE 3. Generalized geologic columnar section.

Era	Period	Series	Group	Thickness*	Important Units
Cenozoic	Tertiary	Pliocene	Ogallala	0–400	
Mesozoic	Cretaceous	Gulf	"Cretaceous"	0–200	
		Comanche			
	Triassic		Dockum	700	
Paleozoic	Permian	Ochoa		1200	
		Guadulupe	Whitehorse	700	
			San Andres	1500	Glorieta
		Leonard		1800	Clear Fork Tubb Wichita-Albany
		Wolfcamp		1600	
	Pennsylvanian	Virgil	Cisco	0–1250	
		Missouri	Canyon	0–1500	
		Desmoines	Strawn	0–1400	
		Atoka	Bend	0–600	
	Mississippian	Chester		0–175	
		Meramec		0–150	
		Osage		0–200	
		Kinderhook		0–150	
	Devonian			0–75	<(?) Woodford Devonian limestone
	Silurian		Hunton	0–300	Fusselman
	Ordovician	Canadian	Ellenburger	0–400	Montoya
	Cambrian			0 (?)–1000 (?)	Wilberns (?) Hickory (?) Granite wash (?)
Precambrian					Basic volcanics Acidic volcanics Metamorphics

*Approximate maximum thickness.

The Middle Ordovician Simpson wedges-out south of the area in Yoakum County. It may be present locally (as filling low areas in the Ellenburger) farther north and east.

Upper Ordovician is represented by the Montoya formation. In the area it is dolomitic although farther south in the Midland basin it is represented by approximately 400 ft of limestone. Typically it is a light brown argillaceous dolomite with subordinate chert. It is believed that the Montoya is not present north of the Matador arch and its eastern wedge-out in the area is to the east of the wedge-out of the overlying Fusselman. This would appear to be evidence for off-lap, but farther south definite transgressive on-lap relationships are reported.

Silurian. The Silurian limestone of the Permian basin is now correlated with the lower Hunton terrane of Oklahoma and is named the Fusselman limestone; the overlying shale is designated only as the "Silurian shale." Ostracods, graptolites, and corals indicate an upper Niagaran age for the majority of the Fusselman.

In the northern portion of the Midland basin, south of the Matador arch, the Fusselman is dolomitic resembling to an appreciable extent the underlying Montoya and the dolomitic members of the overlying Devonian. The lower portion may contain 20-25 per cent chert. The northern limit is essentially coincident with the trend of the Matador arch and the eastern limit is in Hockley and Lynn counties.

Devonian. Definite Devonian strata in the area, consisting of cherty dolo-

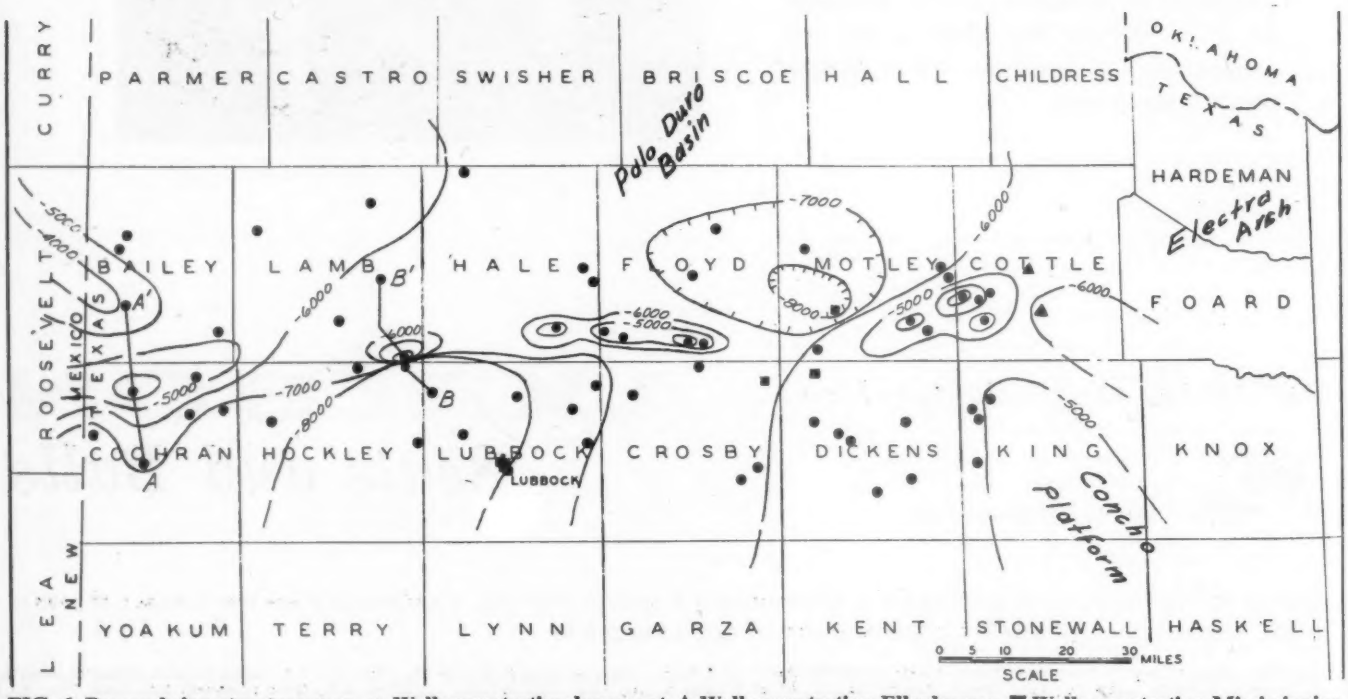

FIG. 6. Precambrian structure map. • Wells penetrating basement. ▲ Wells penetrating Ellenburger. ■ Wells penetrating Mississippian. Contour interval: 1000 ft.

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Unretouched photograph of section of J&L Spring-Kore rotary drilling line worn out in service. Strand removed to expose coiled steel spring core. Note that core looks just like it did the day the rope was made except for faint indentations where wires of the inner strands nested against it for countless ton miles.

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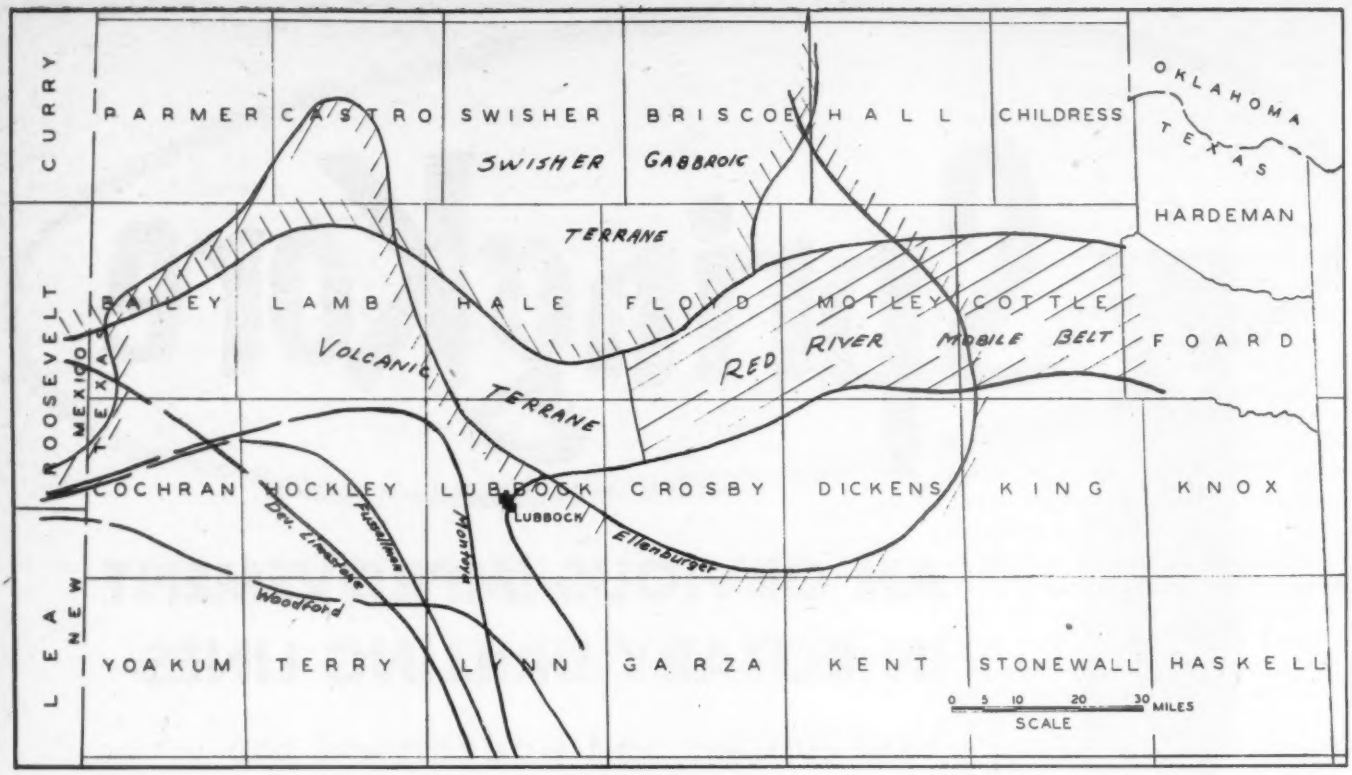

FIG. 7. Composite subsurface geologic map (Precambrian modified after Flawn).

mitic limestones have been called the "Devonian limestone." Above this carbonate section is the Woodford shale. In the Midland basin the Woodford is glauconitic, cherty, pyritiferous, dark brown to black shale containing several layers of dark colored argillaceous dolomite.

The portion of the Woodford found south of the Matador arch in Yoakum, Terry, and Lynn counties is generally represented by a black shale containing a basal argillaceous sandstone in places.

By many the Woodford is considered Devonian, and by others it is thought to be Mississippian. It might be compared to the Chattanooga shale of the Mississippi Valley area in that it may represent late Devonian and early Mississippian sedimentation.

Although the underlying Devonian limestone, Fusselman, and Montoya exhibit off-lap relations south of the arch, the Woodford appears to truncate then in the Lynn County area. This structural relationship would favor a Mississippian age for the Woodford.

Mississippian. Approximately 100 miles south of the Matador arch a thickness of 1100 ft of siliceous limestone of Mississippian age has been encountered. In the Permian Basin the indecisive term "Mississippian limestone" has been used previously for the now defined Osage portion of the Mississippian. At present Kinderhook, Osage, Meramec, and Chester are recognized in the area.

The lowermost unit—probably equivalent to the Kinderhook of the Upper Mississippian Valley—consists mainly of greenish-gray or light brown limestone containing crinoidal material, chert, and gray and green shale. It may range in thickness from 75 to 150 ft.

The Osage is represented by approximately 200 ft of crinoidal crystalline limestone with light gray to blue chert. The Meramec is represented by about 150 ft of limestone, some chert and crinoidal material. Approximately 170 ft of light brown oolitic limestone has been assigned to the Chester. It contains considerable quantities of gray and green shale and fine grained sand.

Some dolomite is present in the Mississippian in local areas near the highs of the Matador structure. Some geologists have expressed the thought that dolomitization occurred in these areas in post-Mississippian time during the major movement along the trend of the Matador arch. In the Palo Duro basin Meramec and Osage sediments directly overlay the Precambrian.

Pennsylvanian. Pennsylvanian sediments of the area have been assigned to the Bend, Strawn, Canyon, and Cisco series; equivalents of the Atakon, Desmoinesian, Missourian, and Virgilian of the Upper Mississippian Valley. Some of the most interesting and challenging studies in the area are those of the Pennsylvanian stratigraphy and paleogeology. Since the discovery of the Scurry County reef considerable impetus was given to the study of Pennsylvanian reef problems in West Texas and eastern New Mexico.

Three characteristic types of sediments are represented by the Pennsylvanian: The basin section of dark shales; the shelf section of limestone, few shales and some evaporites, and the reef accumulations.

Where the Bend is present it may be identified by its arenaceous and arkosic character. It may be present up to a thickness of 600 ft, but usually around 300 ft may be expected.

The thickness of Strawn, Canyon, and Cisco will range to a considerable extent dependent upon whether basin or shelf sections are encountered. The Strawn generally consists of crystalline limestone whereas the Canyon is usually dark gray micaceous shale and the Cisco a black shale where they are in non-reef areas.

The base of the Pennsylvanian is easily recognized—either by the presence of Bend sandstone or the presence of the underlying cherty limestone or dolomites. The top is difficult to determine particularly in the basin sections. The basin shales of Cisco age appear to have the same lithologic features as the overlying Wolfcamp shales. In the areas where reef build-up continued into Permian time the reef lithology continues into the Wolfcamp and no lithologic break is present between the system boundaries.

It has been common practice to call the "top of Pennsylvanian lime" rather than the top of the Cisco. The identifi-

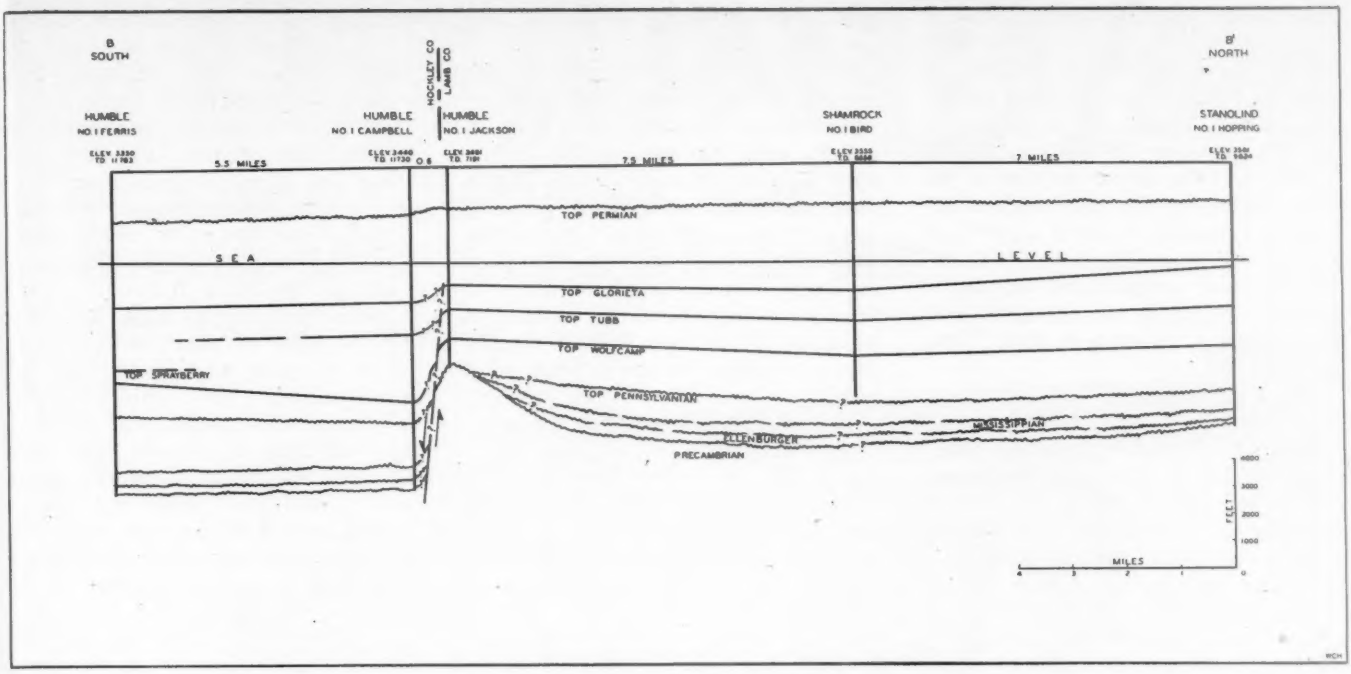

FIG. 8. North-South cross section B-B', Fig. 6.

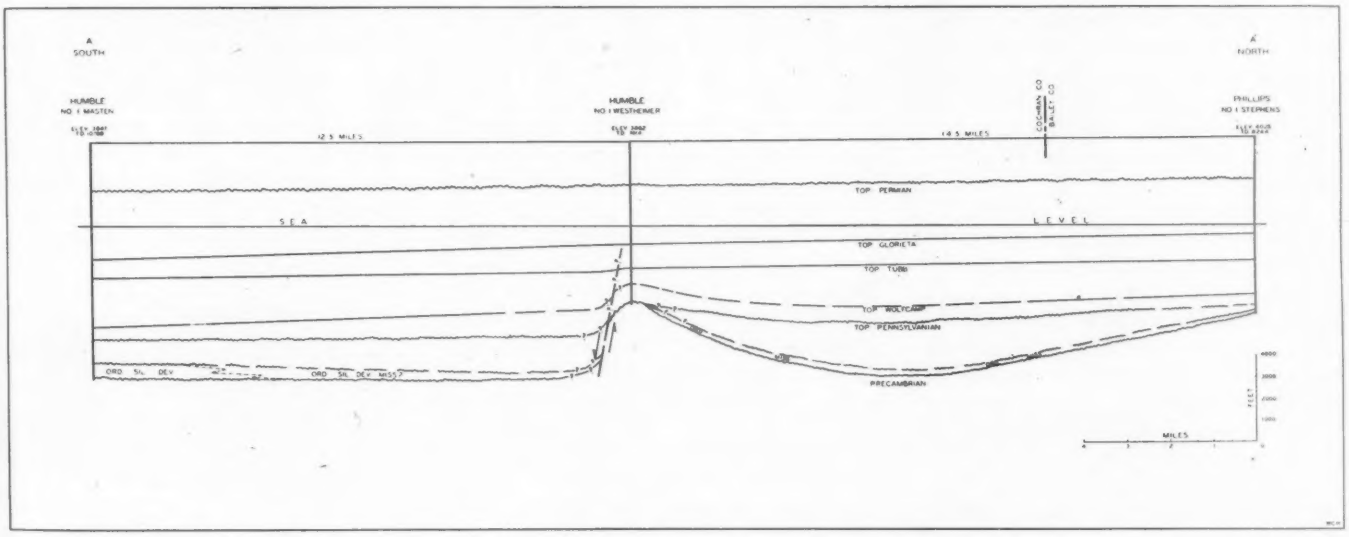

FIG. 9. North-South cross section A-A'. Fig. 6.

cation of the top of the Pennsylvanian is largely dependent upon paleontologic data, and one is fortunate if it may be placed within 50 ft in many instances.

The thickest section of Pennsylvanian sediments occurs in the Palo Duro basin where a maximum of 4500 ft has been drilled.

It has generally been thought that Pennsylvanian sediments were absent over the crest of many of the Precambrian highs but recent paleontological data indicate that there is a strong possibility that thin sections of Strawn, Canyon, and Cisco sediments may be present on the highs.

Permian. Sediments of the Wolfcamp, Leonard, Guadalupe, and Ochoa series are present in the area. Approximately 1600 ft of gray and brown shales with numerous limestone and dolomite layers constitute the Wolfcamp. It thickens southward to over 5000 ft of clastics in Pecos County and thickens regionally westward in contrast with the Pennsylvanian. Reef type limestone is found in places where reef build-up persisted through the Cisco into the Wolfcamp. The Dean—an excellent sandstone marker horizon in the Midland basin—does not extend as far north as the Matador arch.

In southeastern New Mexico lagoonal facies of the Leonard, Guadalupe, and Ochoa are recognized. In the Matador area and to the east these sediments appear as shelf type facies and gradually merge into the lagoonal facies westward.

The Leonard series is conveniently divided into the lower and upper. The lower portion consists of the famous Spraberry of the Midland basin. In eastern New Mexico its equivalent is the Abo, consisting of red shale, sandstone, and arkosic material. In the local area this portion has generally been called the Wichita-Albany and consists of approximately 1000 ft of dark shales (in the basin sections) becoming lighter and more red in color in the shelf areas.

The upper portion of the Leonard, or the Clear Fork, has been an important producing horizon in the area and consists of approximately 750 ft of red shales, anhydrite, and salt. The "Tubb" sand near the base of the Clear Fork is an excellent marker in the subsurface either on lithologic or electric logs. This upper portion has not been named in the Midland basin but the lagoonal facies in eastern New Mexico is the Yeso.

Approximately 400 ft of gray, fine grained, sandy dolomite that becomes

more sandy westward forms the lower portion of the Guadalupe and had been named the Glorieta. The Glorieta is the lowest unit in the somewhat loosely defined San Andres and is at least a partial equivalent to the San Angelo to the east. The upper portion of the San Andres, or the San Andres (restricted), consists of about 1100 ft of fine grained crystalline dolomite. It bebecomes finer grained and contains a greater percentage of anhydrite and fine clastics westward into New Mexico.

The upper portion of the Guadalupe is named the Whitehorse group and consists of alternating layers of dolomite, sandstone, shale, and limestone. Northward and westward the clastic ratio increases as does the percentage of evaporites. The Yates, a reddish gray sandstone and shale, contains frosted quartz grains and is an important and readily recognized marker horizon.

The Ochoa consists largely of evaporites (anhydrite and salt), red shales, and minor dolomite layers. It is customary to call the "top of the anhydrite" rather than the top of the Permian, as the first anhydrite encountered may be as much as 150 ft below the top of the Permian. The Ochoa is represented by approximately 900 ft of sediments.

Post-Paleozoic. Triassic redbeds occur above the Permian throughout the area and consist of red shales, siltstones, and fine grained sandstones which may attain a thickness of around 700 ft. They have been divided into Tecovas, Santa Rosa, and Chinle formations of the Dockum group.

No Jurassic sediments are known in the area.

Lower Cretaceous sediments consist of sandstone, limestone, and shale that overlie the Triassic from southern Bailey County southeastward. Cretaceous rocks crop out around the edges of shallow playa basins in Lynn, Lubbock, Lamb, and Bailey counties.

The Ogallala of Pliocene age blankets the southern high plains with up to 700 ft of poorly consolidated sands, clays, and gravels. This portion of the Ogallala is perhaps the largest individual underground aquifer known today. It supplies irrigation water to an area that extends from Amarillo south to Dawson County and from the cap rock in Floyd and Crosby counties west into New Mexico. Caliche deposits are numerous within the Ogallala and form the cap rock on the eastern and western edges of the high plains.

Conclusion

Interpretations of the geologic history and structural relationships of the Matador arch have been discussed, at least briefly, for some time but no comprehensive work has been published on the area.

One situation that has hindered such a study is that district boundaries of numerous oil companies have been the county lines that are roughly coincident with the Matador arch. This is particularly noticeable in the terminology of Permian sediments. North of the arch the North-Central Texas terms are in vogue, whereas south of the arch Permian basin terminology is used. As we know, it has been difficult to give proper attention to fringe areas of a district.

A confusing item has been the terminology relating to the structure itself; that is whether one is referring to the Precambrian, early Paleozoic, or late Paleozoic structural features. If one is referring to the Precambrian, the Matador is a series of peaks or a range of mountains; if early Paleozoic time is indicated, perhaps it might be called an archipelago; and if one is referring to the late Paleozoic the structure represented is a broad warp or flexure.

Along the trend of the Matador arch there are no wells penetrating the basement lows indicated on the map, Fig. 6. That such lows are present is highly suggested by the attitude of upper Pennsylvanian and Permian sediments in the area and by interpretative geophysical data. Not only are the dips reversed on the north and south of the structure but peripheral dips of the Permian are encountered in several area along the trend of the structure.

Many geologists concur with the idea that the structure may be dated as early Pennsylvanian, probably Bendian. The writer believes, however, that it had its conception and was a definable structural unit in late Precambrian time although admitting the major movement now apparent (amounting to a displacement of at least 2500 ft) may have occurred during the late Paleozoic.

From regional studies it is quite noticeable that the area of "no Ellenburger" is roughly equivalent to the area that Flawn had designated the Swisher gabbro terrane plus the eastern portion of the Matador arch (Fig. 7). This parallelism does not agree in the area of the northernmost extension of the Ellenburger in the western part of the area in Castro County and in the southeastern area of "no Ellenburger." The boundaries do suggest, however, that there is a relationship between the area underlain by the Swisher gabbro terrane and the area where the Ellenburger is absent. Perhaps the controlling factor may have been the presence of a land mass of low relief formed by the basic extrusions which constitute the gabbro terrane.

Another somewhat fortuitous relationship exists—if one postulates movement in Bendian time — where the wedge-out limits of the Montoya, Fusselman, and Woodford are found to bend westward roughly paralleling the trend of the structure. Devionian limestone has been recognized north of the arch in Bailey County but farther westward its wedge-out bends southward to a position roughly coincident with the Matador arch trend.

Although a great deal has been learned about the area during the past 10 years, many problems remain unsolved and have been approached only by interpretative studies. Oil shows in the Palo Duro basin have kept interest alive in that area and the sparse well control has condemned only a minute portion of the area. Many detailed geologic studies are in progress attempting to solve a number of the unanswered questions and, I am sure, the result will point the way for further exploration programs in the Matador arch area.

Acknowledgments

Assistance from the Lubbock district office of the Stanolind Oil and Gas Company in permitting examination of certain logs is gratefully acknowledged. The writer wishes to express appreciation for the helpful discussions with Ray C. Morris, Marvin L. Shapiro, and Thomas F. Newkirk.

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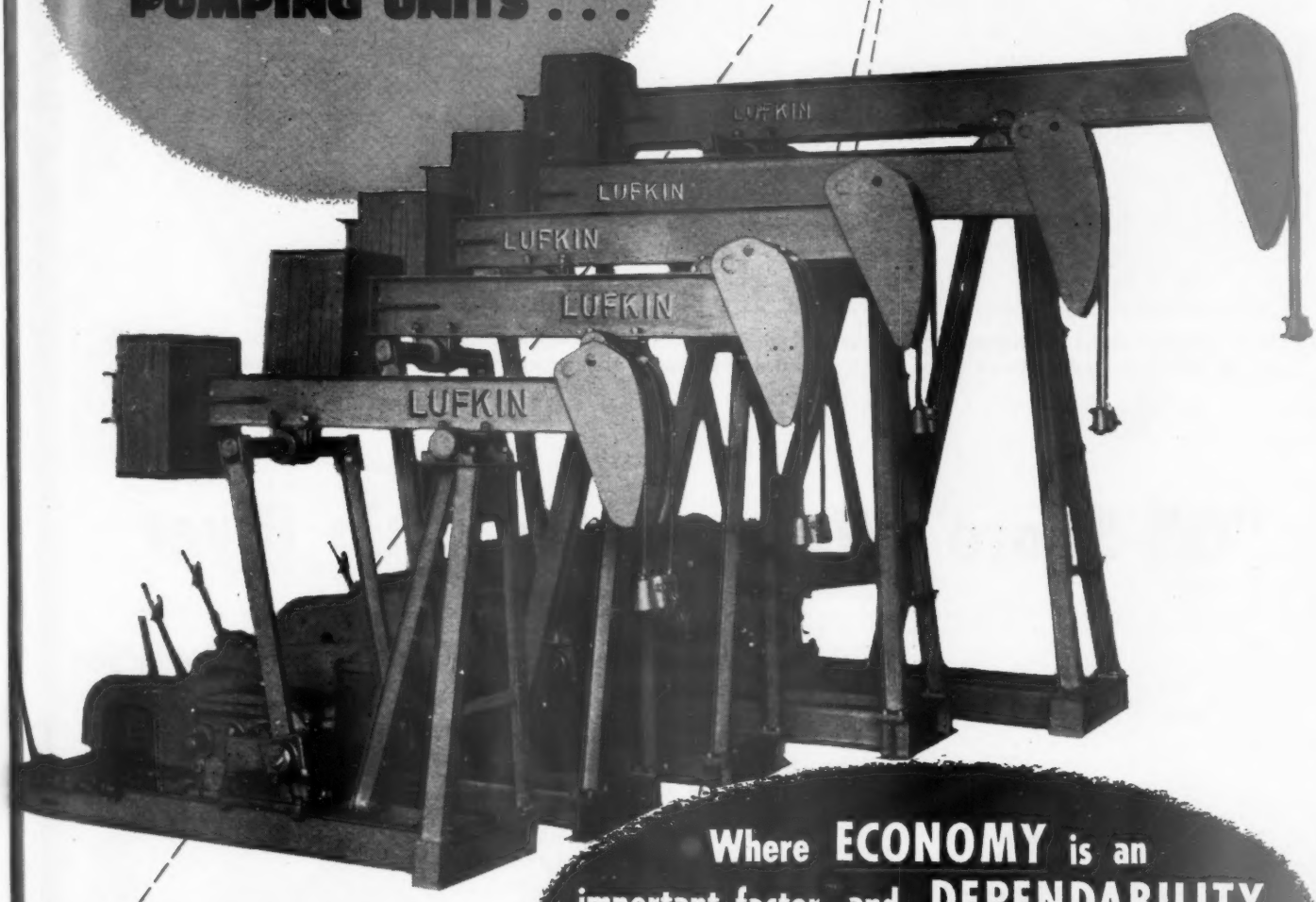

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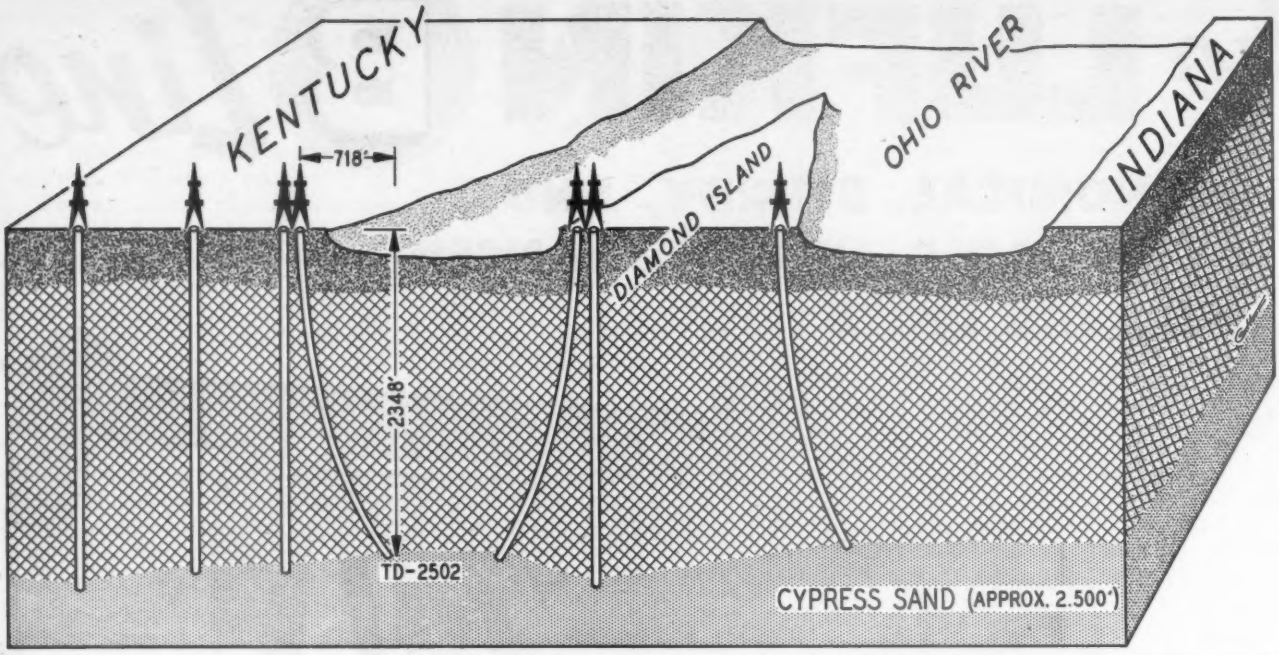

FIG. 1. Diagram shows development of the North Smith Mills pool of Kentucky. Three holes have been drilled directionally under the river from the Kentucky shore, and four drilled directionally from Diamond Island northward towards Indiana.

"Off-Shore" Wells on the Ohio River

. . . mark Carter Diamond Island area production

A. M. ROWLEY*

THE Carter Oil Company is obtaining good crude oil production from beneath the bed of the Ohio River through directional drilling from the Kentucky shore and from an island in the middle of the river.

As far as is known, this is the first time crude oil production has been obtained from under a large, navigable river through directional drilling.

Operation is being carried on in the North Smith Mills pool of Kentucky, near Henderson, and about 15 miles southwest of Evansville, Indiana. Carter has 21 producing oil wells in the pool and one dry hole. Of the producers, 7 are directionally drilled holes, 3 from the Kentucky shore and 4 from Diamond Island, in the middle of the river and north from wells on the Kentucky shore. All 7 are bottomed under the river.

The wells are capable of producing between 250 and 300 bbl of 35 to 36 gravity oil per day and are on the pump. Wells on the Kentucky shore are connected to the pipe line gathering system in the pool. Production from wells on the island is barged to the Kentucky shore and picked up there by the pipe line gathering system.

The oil-bearing horizon, called the Cypress sand, is found at a depth of generally 2500 ft, less in some places under the Ohio River bed. It extends under the river bed north from the Kentucky shore, also under Diamond Island, and to the north, under the river bed between the island and the Indiana shore.

One of Carter's directional wells was drilled on the north shore of the island and curved towards the Indiana shore and bottomed under the river bed between the island and the Indiana shore. It was a producer with an average daily output about the same as the other wells drilled in the pool.

Carter started its drilling campaign in the pool late last year. Its first well

EXCLUSIVE

FIG. 2. Typical sub-structure on Diamond Island. This one is 27 ft high— believed to be the highest operated by Carter Oil Company.

*Oil writer for the Tulsa Tribune, Tulsa, Oklahoma.

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was located about one-half mile south of the Ohio River in Kentucky. It kept extending the pool to the north until it drilled a well practically on the south bank of the river.

Wells in this area were drilled from substructures rising 20 ft above surface ground because of floods which inundated the territory every year. Wells drilled on the island have substructures as high as 27 ft.

When producing wells were completed on the river bank, Carter moved over to Diamond Island and drilled a well straight down along the south side of the island. It was a producer of 300 bbl a day from the Cypress sand.

Carter then decided to drill a directional hole from the Kentucky shore, curving it to the north and bottoming it under the river between the Kentucky shore and the island. This well, the No. 10 Waller, was drilled from an extension of the same substructure

FIG. 3. Looking from the floor of a substructure 27 ft above Diamond Island.

from which a straight hole, No. 8 Waller, had been drilled.

No. 10 Waller was drilled 400 ft straight down and then a whipstock was set to curve the hole to the north. After 14 whipstocks had been set, No. 10 Waller was bottomed under the bed of the river, in the Cypress sand, at a total depth of 2502 ft and a vertical depth of 2348 ft. It was bottomed 718 ft north and 63 ft east from the exact spot on the river bank from where drilling started. On initial test, it made 224 bbl of oil, without any water, in 24 hours.

The Ohio River at this point is three-quarters of a mile wide. Diamond Island is three miles long, east and west, with the west end coming to a point. Drilling has been done on this part of the island, to a point where the island is about one-third mile wide.

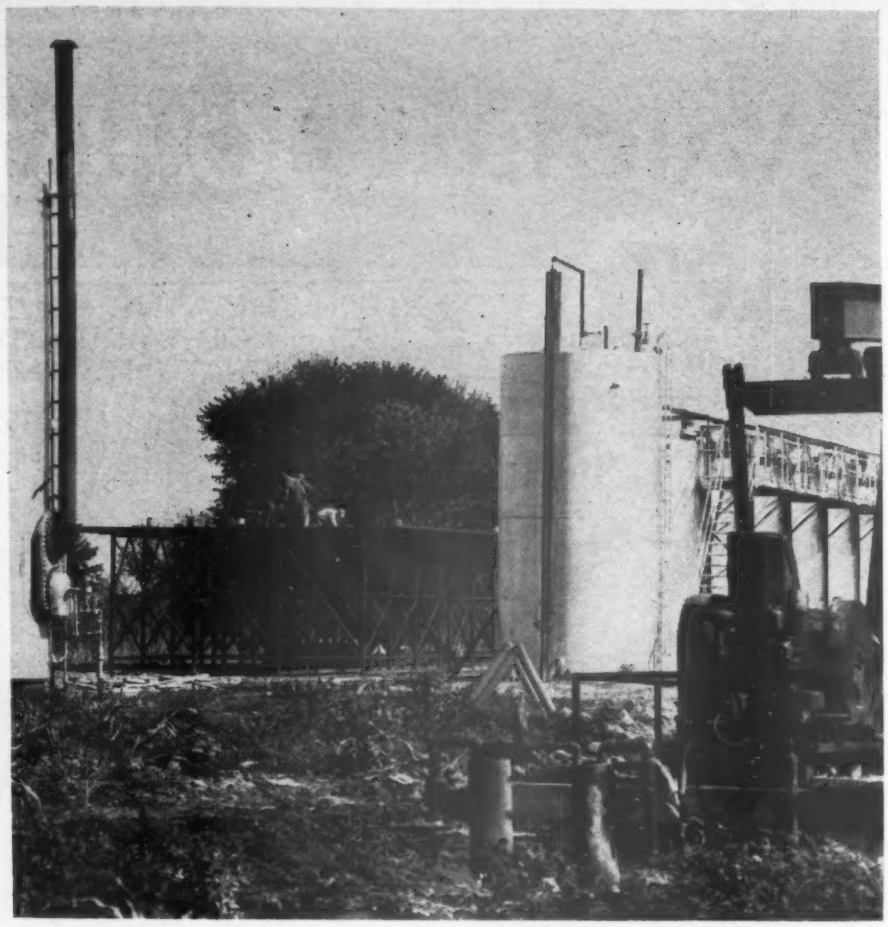

FIG. 4. Temporary tanks on Diamond Island which will be mounted on the sub-structure at left. Oil from island is hauled by barge to the Kentucky shore where it is picked up by the pool gathering line.

The North Smith Mills pool is about one and one-half miles long, north and south, and about three-quarters of a mile wide, east and west.

The United States Corps of Engineers controls operations on the Ohio River as it is a navigable stream. The engineers must approve the route of any barge line between the Kentucky shore and the island, or any pipe line that may be built under the river between the Kentucky shore and Diamond Island.

All wells in the pool are drilled by rotary to near the top of the sand, from which point they are completed with spudder or cable tool. * * *

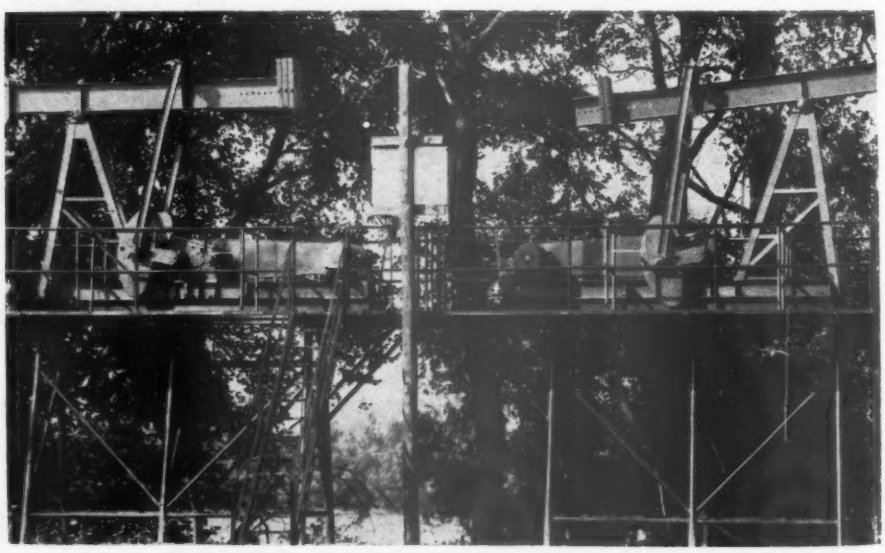

FIG. 5. Two pumping units mounted on a single sub-structure. Well on the left is straight, the one on the right is the whipstocked No. 10 Waller.

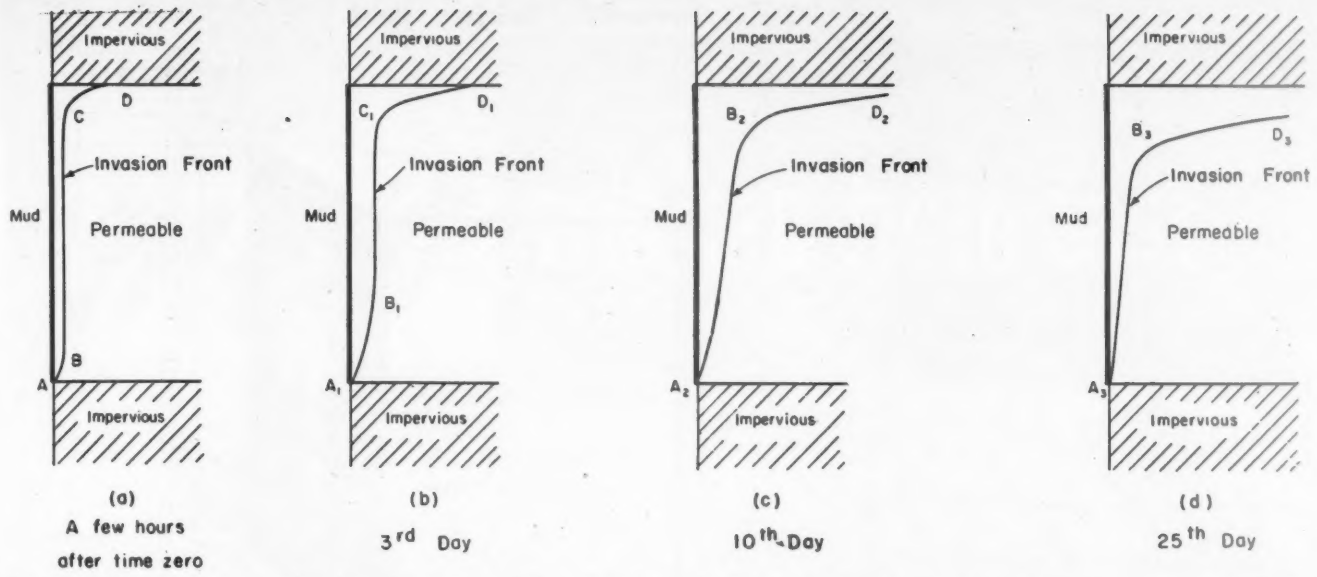

FIG. 1. Filtrate density less than connate water density. Time zero: Beginning of invasion. (Times shown are merely illustrative.)

A STUDY

Filtrate Invasion in Highly Permeable Sands

Depth of invasion often appears less in base than in upper portion of highly permeable sands. Conclusion is that filtrates rise in sand after passing filter cake barrier at hole wall.

H. G. DOLL

IT has often been observed in salt-water bearing sands of high permeability that the depth of invasion by mud filtrate is quite small near the bottom boundaries of the beds, whereas the top parts of the beds are deeply penetrated. This feature was brought to light by the resistivity logs, in which the shallow investigation curve (short normal) gives the same very low readings as the deep investigation curves (long normal and/or lateral) over the lower part of the beds, and an appreciably higher reading over the upper part.

Further evidence isprovided by the micrologs, which show respectively negative and positive separations opposite the lower and the upper portions of the beds. Examples of this behavior are exhibited in Figs. 12 and 13.

This observation has suggested the idea that, in this kind of formation, after the mud filtrate has been forced through the mud cake, it does not flow horizontally into the formation, but has a tendency to rise.

The mud filtrate is most often much less saline than the interstitial water originally located in the pores and its density is therefore appreciably smaller. As a result of this difference in densities, the mud filtrate is submitted to an ascensional force. Its velocity is the resultant of two components: One vertical (upward) component, caused by the ascensional force, and one horizontal (radial) component, due to the rate of filtration.

Considering a permeable bed, bounded by impervious formations, and thick enough that the upward movement of mud filtrate in the lower part of the bed is not affected too much by the presence of the upper impervious boundary, the vertical component of filtrate velocity in the lower part is essentially proportional to the ascensional force and to the vertical permeability of the formation. So, when this latter is great, the vertical component may be substantially larger than the horizontal component, which itself is comparatively small because the sealing properties of the mud cake limit the rate at which filtrate can enter the formation from the hole. Actually, as will be shown in more detail in the Appendix, a value of the order of 2 ft per day seems a reasonable figure for the vertical component in high per-

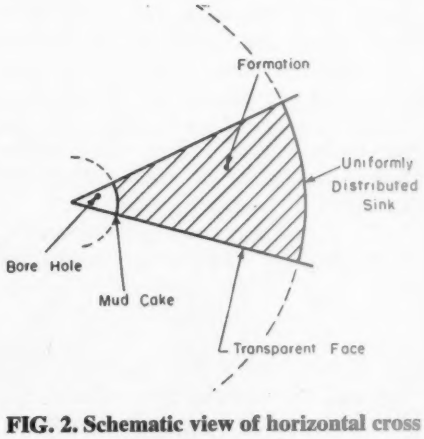

FIG. 2. Schematic view of horizontal cross section of laboratory model.

EXCLUSIVE

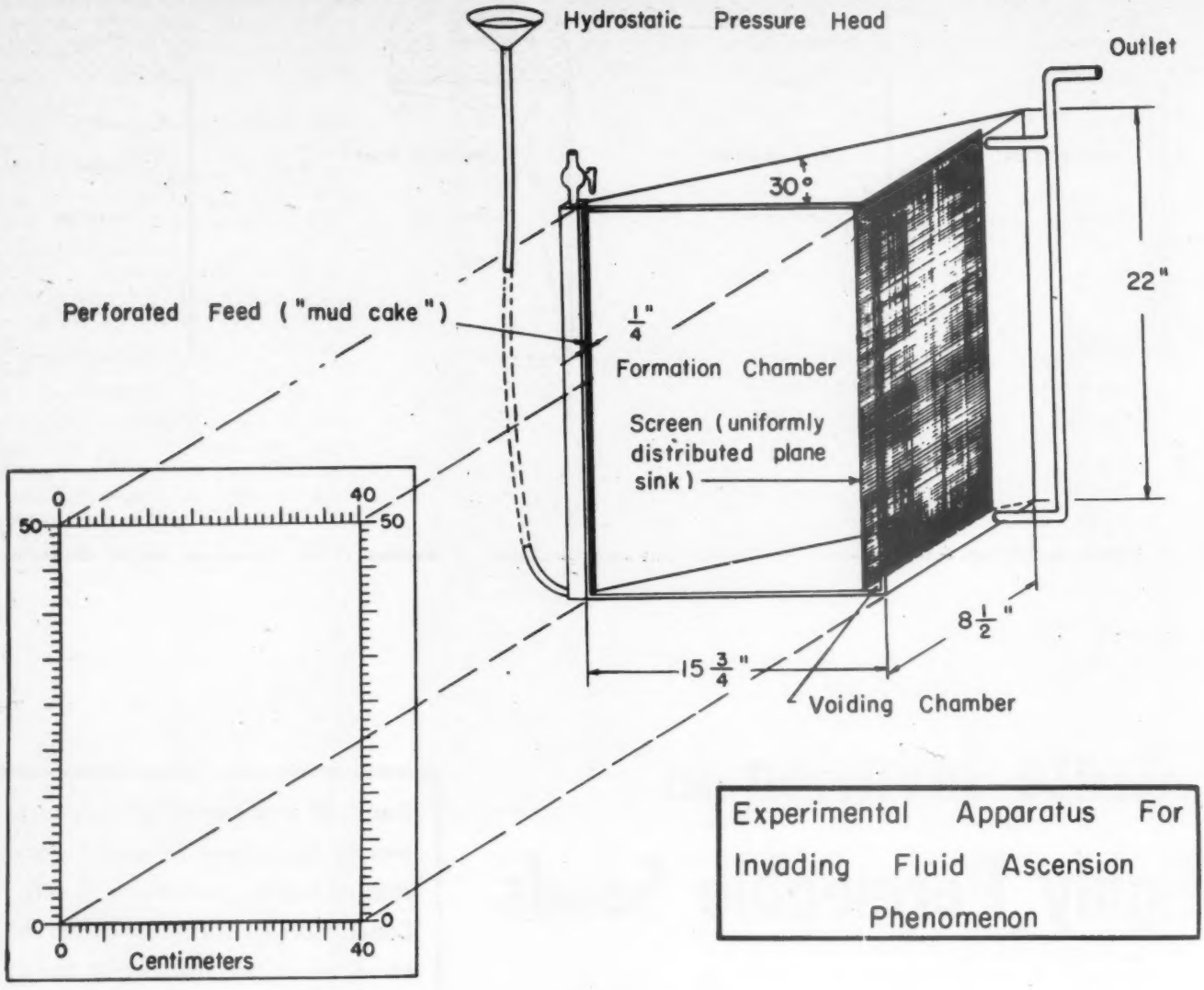

FIG. 3.

meability formations, with the usual differences between mud filtrate and connate water densities, whereas the horizontal component of filtrate velocity radially out from the hole wall is known to be of the order of a few inches per day at the most.

Consequently, in the lower part of the formation, the mud filtrate rises obliquely from the wall of the hole, and the invasion is shallow; in the upper part, the mud filtrate accumulates below the upper boundary, and the invasion is deep. By analogy with the displacement of the fluids contained in a vessel under the action of temperature differences, this ascensional movement of mud filtrate will be called a "convection current."

The invasion process in a permeable, homogeneous and salt-water-bearing bed, bounded by impervious formations, is shown schematically on Fig. 1.

In tracing the figure, it has been assumed that there is no transition zone between the invaded and non-invaded parts of the bed, which means that the diffusion from connate water into filtrate can be taken as negligible. It has been furthermore assumed that the drilling speed is so great with respect to the speed of filtration that invasion begins substantially at the same time throughout the whole permeable formation. The time of the beginning of invasion will be taken as time "zero" in the following discussion.

Shortly after time zero, say a few hours, the surface separating the invaded and the non-invaded zones, which will be referred to in the following as the "invasion front," is still quite close to the wall of the hole, and its shape, as indicated in Fig. 1a by the line ABCD, includes a central vertical section BC*. As the invasion front moves forward the vertical portion shrinks, as shown for example by the curve $A_1B_1C_1D_1$ of Fig. 1b, representing the conditions existing on the third day after time zero. Still later, for example on the 10th day, all the filtrate that had penetrated the bed at time zero has had time to reach the top boundary. At that time the invasion front no longer contains a vertical section, but has assumed the shape qualitatively shown by curve $A_2B_2D_2$ in Fig. 1c.

Furthermore, the rate of filtration, and hence the radial component of filtrate velocity, decreases progressively with time as the mud cake becomes thicker, whereas the vertical component should be constant with respect to time and to space (see Appendix). The result is that the direction of the lines of flow have a tendency to come closer and closer with time to the vertical. The invasion front therefore moves forward for several days after time zero until a maximum extension of invasion is attained, (for example, until the 10th day, as shown in Fig. 1c), and then, in the lower part of the bed, it recedes progressively, whereas in the upper part it continues to expand below the upper boundary (Fig. 1d — curve $A_3B_3D_3$: 25th day).

This qualitative description will be elaborated by the results of laboratory

*To simplify the wording, terms like ABCD, which designate the intersection of a surface of revolution with the plane of the figure, are used in this article to denote the surface itself.

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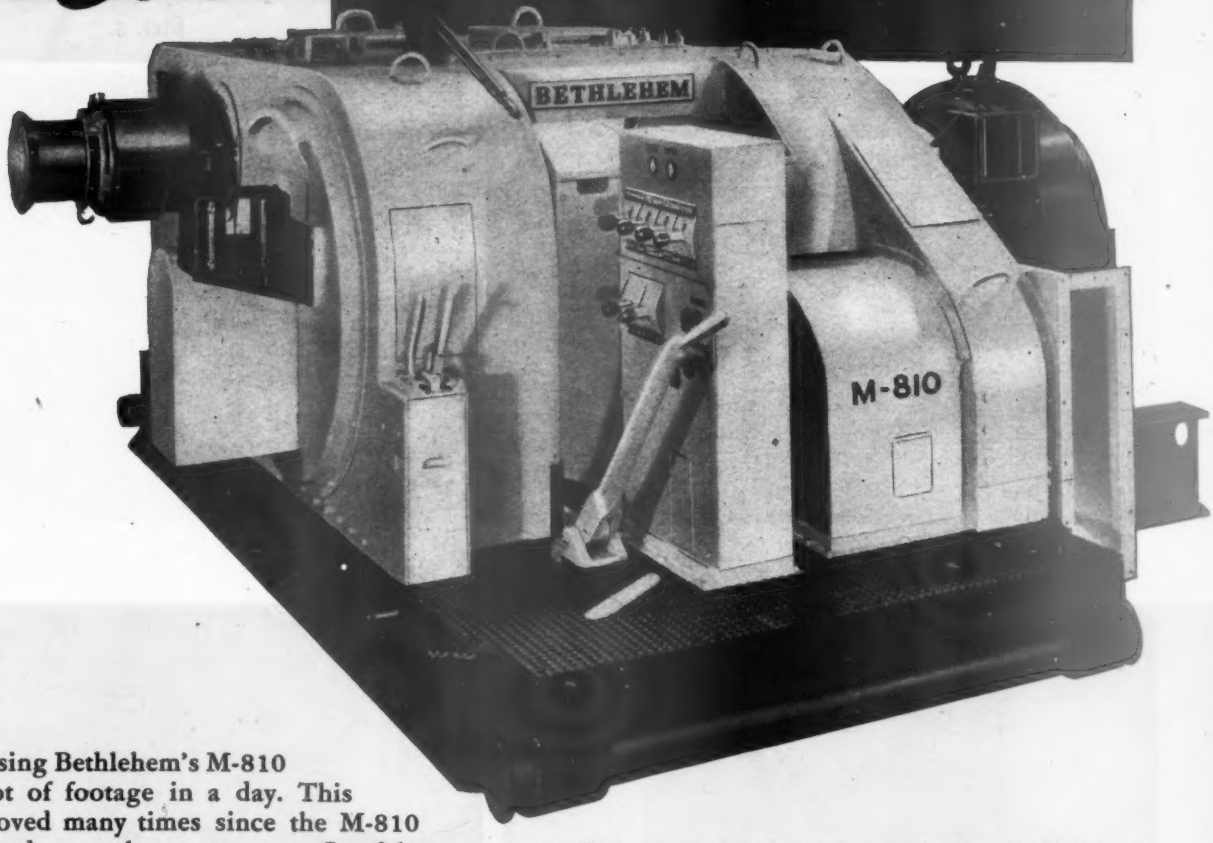

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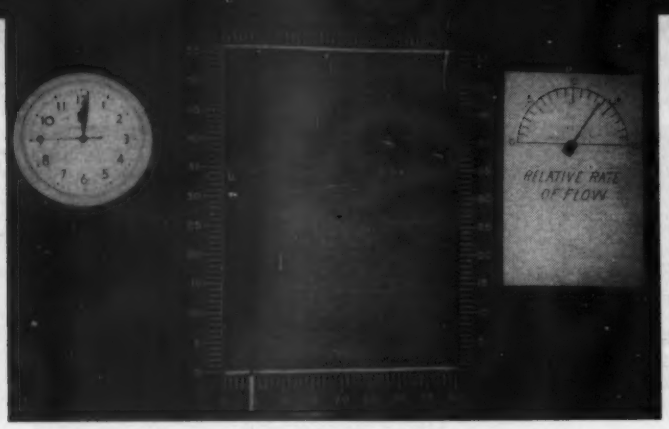
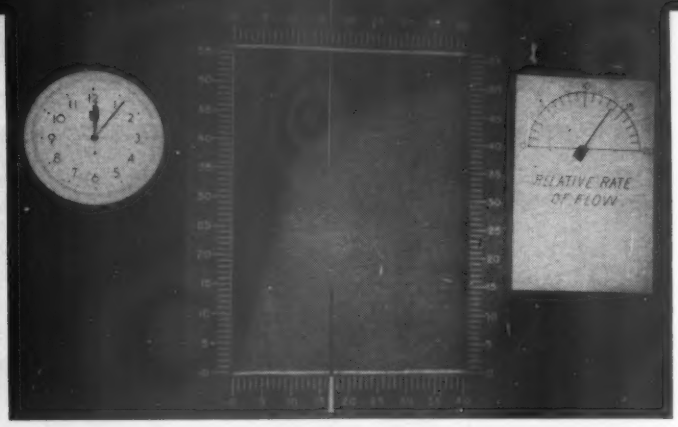


FIG. 4.



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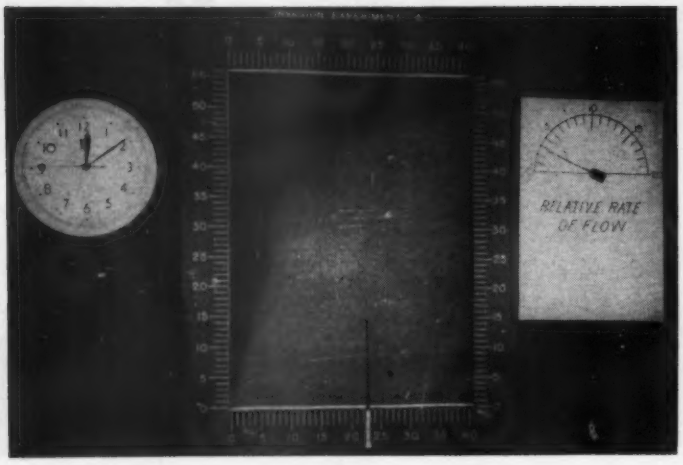
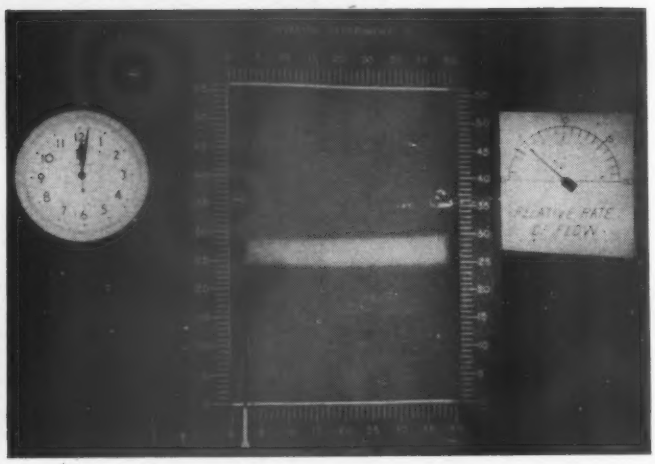


FIG. 6.



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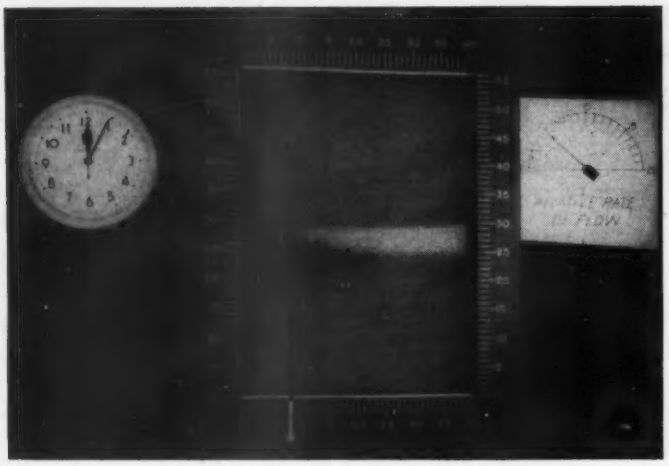

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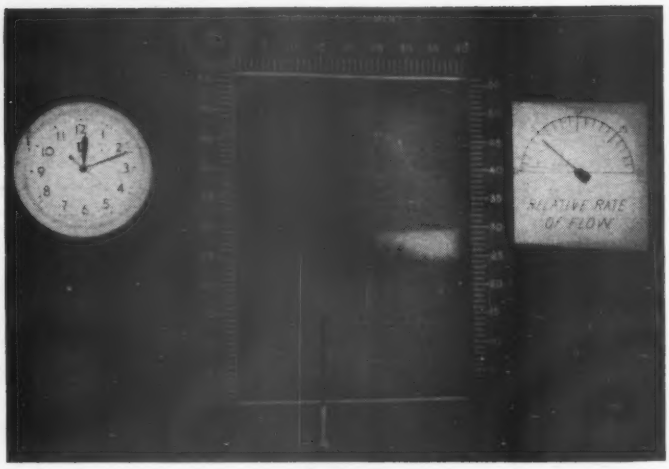

FIG. 9.

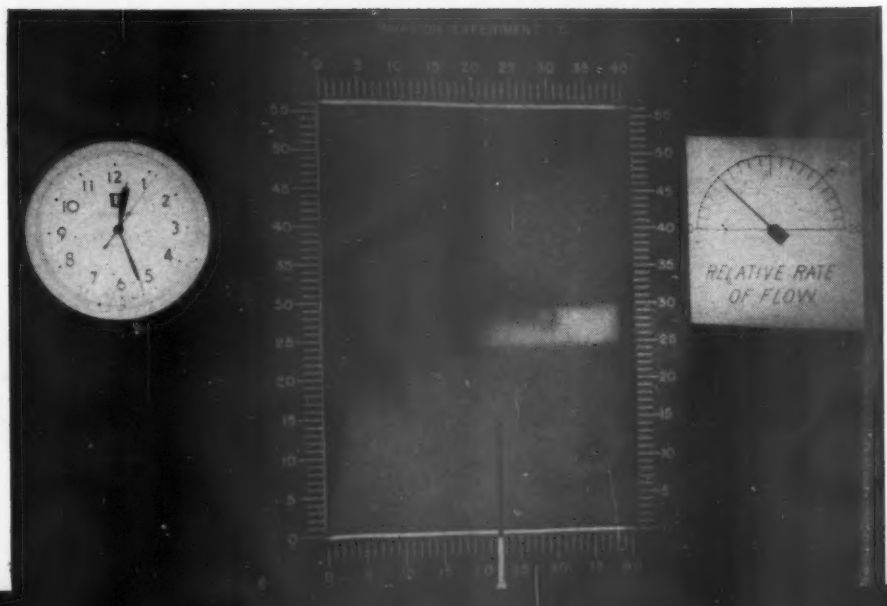

FIG. 10.

FIGS. 4, 5, and 6. Invasion process in homogeneous formation of 4500 darcies.

FIGS. 7, 8, 9, and 10. Invasion process in permeable formation (4500 darcies) including a less permeable section (230 darcies).

(The pointer at bottom indicates depth of uniform invasion.)

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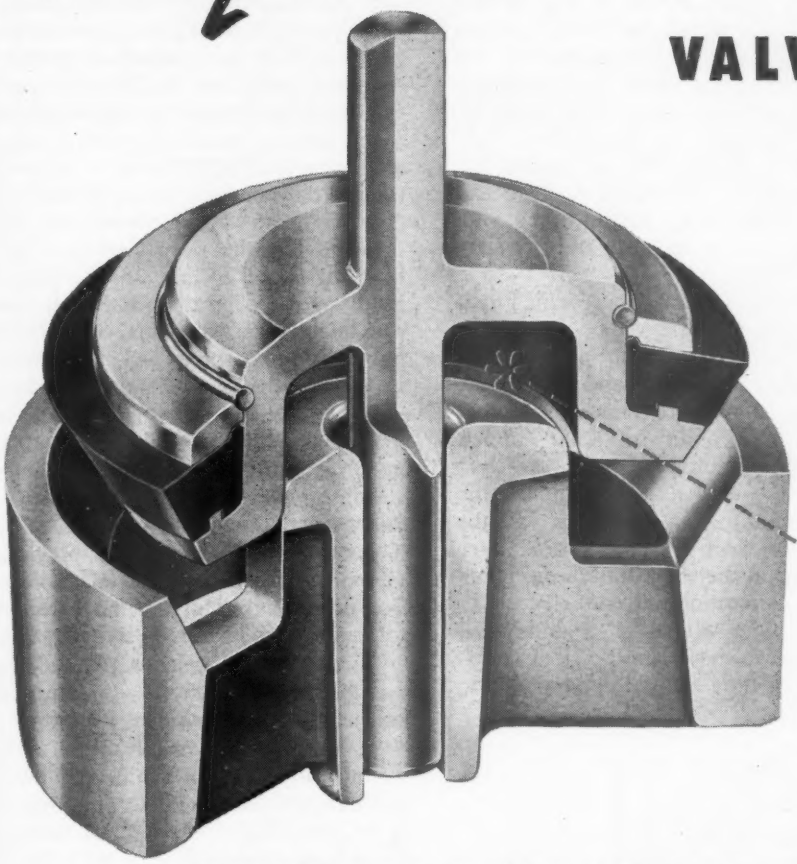

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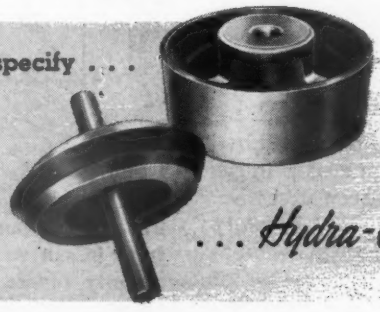


. . . *Hydra-Cushion*

The Author

Henri-Georges Doll was graduated from the University of Lyon, France, with a bachelor of science. He did graduate work at the Ecole Polytechnique and the Ecole Nationale Supérieure des Mines de Paris. He was first employed as research engineer for the Société de Prospection Electrique (Procedes Schlumberger), Paris, France, from 1926 to 1939. From 1934 to 1939, he was technical consultant for Schlumberger Well Surveying Corporation, Houston, Texas. In 1940, he became director of research for Schlumberger, and in 1941 chairman of the board of directors.

Doll was awarded a Certificate of Appreciation by the U. S. Government for his work on mine detectors, and the Legion of Honor Medal by the French Government for his technical achievements.

tests and of mathematical computations to be explained hereafter.

Laboratory Experiments

Procedure. The invasion process in highly permeable formations was studied by means of a laboratory model, consisting essentially of a chamber that could allow radial invasion. To this end, the model approximated a "pie-shaped" sector cut from a cylinder, as shown in Fig. 2. To represent the mud cake use was made of a metal strip closing the narrow edge of the "pie-shaped" cavity. This strip was perforated with many evenly distributed capillary apertures through which "mud filtrate" could be forced into the "formation." The permeable formation was made of spherical glass beads of uniform diameter. In order to make possible free radial invasion the outer periphery of the model was terminated by a screen, which served as a uniformly distributed sink for the flow of fluids (Fig. 3). The top and bottom boundaries of the pie-shaped box represented impervious beds above and below the glass bead formation.

The permeabilities of the mud cake and of the formations were chosen quite large, at least one thousand times larger than in usual field conditions. This was done because it was difficult to build a simulated "mud cake" with a low enough permeability. Also, for lower permeabilities the time required for the phenomenon to develop in the laboratory would have been excessive. In fact, the time in the laboratory tests was counted in minutes, whereas in actual conditions it is a matter of days.

One plane face of the model was transparent, which enabled the recording of the evolution of the phenomenon by means of photographs taken at proper intervals of time. To this end, and also to facilitate the visual inspection of the experiment, a special dye (potassium permanganate) was used to color the filtrate water.

The pressure needed to cause the flow of the filtrate into the invasion chamber was provided by a water column, the hydrostatic head of which could be varied at will. It was verified that the rate of flow of the filtrate into the chamber was proportional to this pressure, as measured by a mercury manometer connected at the lower inlet of the simulated mud cake.

A dial, the reading of which was proportional to the pressure on the filtrate, is shown in the accompanying photographs to indicate the "relative rate of flow."

In all experiments, the specific gravities of the connate water and of the filtrate were respectively 1.04 and 1.

Results. Figs. 4, 5, and 6 illustrate the case of a homogeneous formation, with a permeability of 4500 darcies.

On each photograph, the pointer at the bottom of the frame indicates the depth of uniform invasion, i.e. the depth to which invasion would have extended in the same time, were it not for the convection currents.

The times after the beginning of invasion are shown on the clock: Each minute of time elapsed corresponds to about 3 days for a formation with a usual permeability of 1000 md (1 darcy).

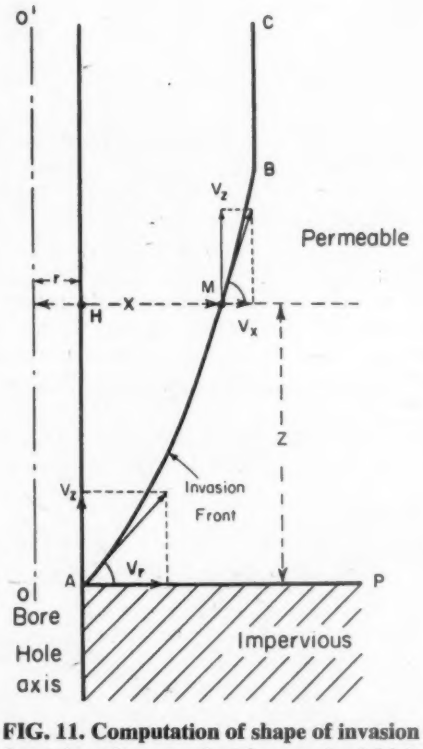


FIG. 11. Computation of shape of invasion front in salt water bearing sand of high porosity (upper boundary at great distance).

In Fig. 4, invasion is just beginning, and the invasion front is substantially vertical between altitudes 10 and 50. The distance of this vertical front from the wall of the hole is substantially equal to the depth of uniform invasion, as shown by the pointer (except for some diffusion).

Fig. 5 shows the invasion front, six minutes after the beginning of invasion (18 days for a 1000-md formation). As the rate of invasion has been kept constant, an equilibrium position has been established. In the lower part, the depth of invasion is much smaller than would be in case of uniform penetration, as is clearly shown by the position of the pointer. Above altitude 37 the filtrate has accumulated, and the invasion is quite deep. Between altitudes of about 25 and 35, the photograph shows a portion that looks approximately vertical: this is likely to be caused by some lack of homogeneity in the glass bead formation.

Fig. 6 shows the situation after 9 minutes (equivalent to 27 days for 1000 md). In the meantime, the rate of invasion had been reduced (the relative flow of rate, shown by the meter, reads 3 instead of 14, as in the previous views). As could be expected, a recession of the invasion front, with respect to its position in Fig. 4, is noticeable.

Further experiments were made to investigate the effect of variations of permeability within a bed.

To illustrate the results, Figs. 7, 8, 9, and 10 show the evolution of the phenomenon in a model containing a permeable bed, 4500 darcies divided by a horizontal section with a lower permeability (230 darcies).

In Fig. 7, just after the beginning of the invasion, mud filtrate shows a tendency to accumulate underneath the boundary between the lower more permeable portion and the less permeable section. The same tendency is observed also near the top boundary of the model.

Fig. 8 shows the invasion after 4 minutes (12 days for 1000 md). Some vertical channeling is visible within the intermediate section.

After 12 minutes (36 days), the channeled filtrate has extended into the upper more permeable part of the bed (Fig. 9).

Finally, as the rate of filtration has been kept constant, an equilibrium position is practically reached after 26 minutes (i.e. 78 days), as shown in Fig. 10. The invasion appears to be very shallow throughout most of the lower permeable part of the bed, then an abrupt increase occurs near and

below the lower boundary of the less permeable section. From this level the invasion remains approximately at the same depth, and then increases again near the top boundary of the upper permeable part of the bed.

Of course, in the upper half of the model, the invasion front is not clearly defined because of the influence of channeling. The invaded zone actually does not contain only mud filtrate, but a mixture of filtrate and connate water.

The experiment seems to show that when a high permeability bed includes a section with a lower permeability, a regime of convection currents builds up such that the invasion is shallow only below the less permeable section.

Computations

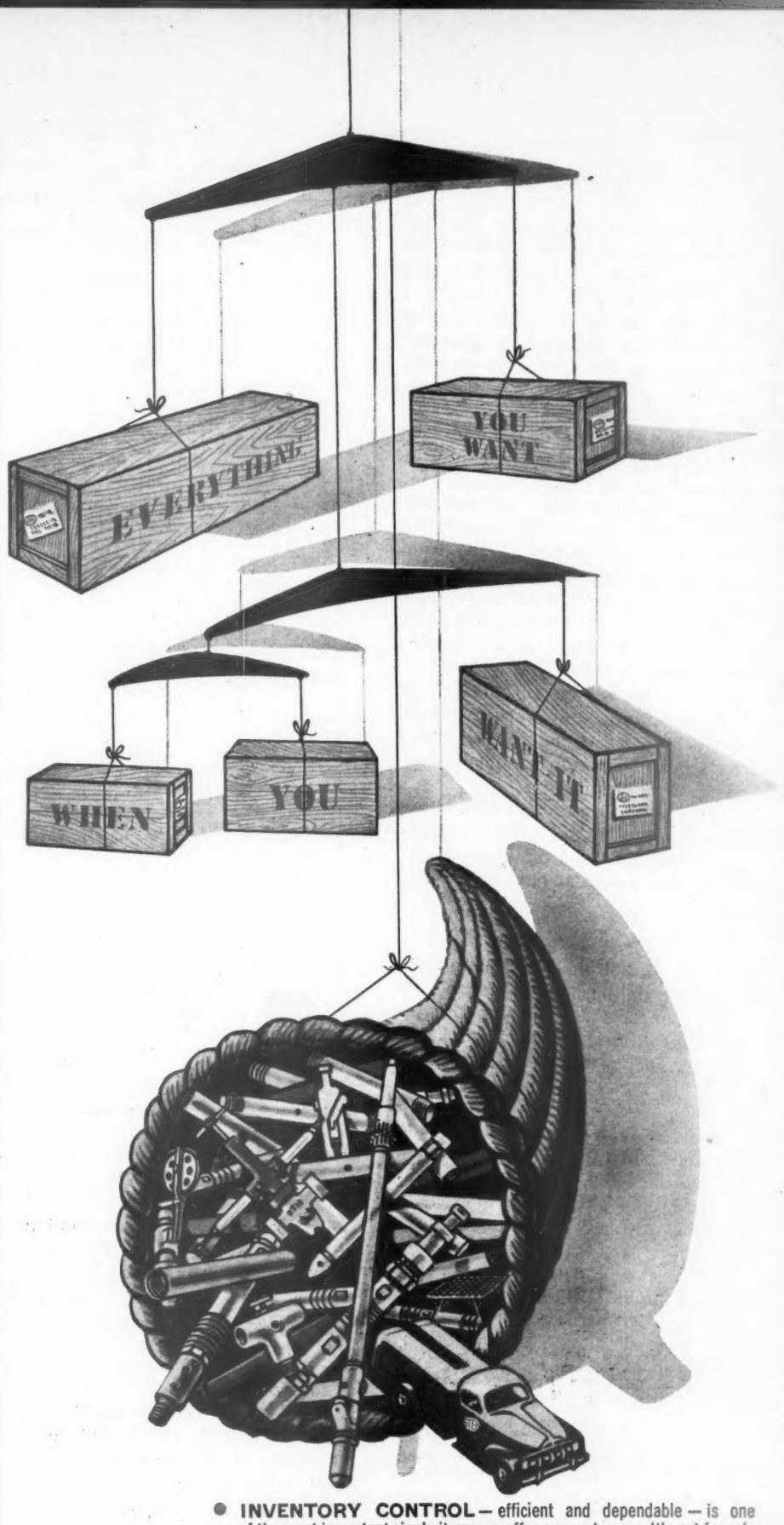
The shape of the invaded front can be computed approximately for the lower portion of a homogeneous permeable bed again supposed to be thick enough that the presence of the impervious upper boundary has a negligible influence on the circulation of the fluids in the lower part.

Fig. 11 represents the vertical cross-section of the lower part of such a permeable bed. In this figure, the vertical distances, z, are measured from the lower boundary AP, and the horizontal distances, x, are measured from the axis 0 0′ of the bore hole.

Considering a certain point M of altitude AH = z on the invasion front, the computations were made supposing that all the mud filtrate, which had crossed the wall between A and H at time zero, has already ascended above the level of M. In other words, the vertical portion of the invasion front (such as A_1B_1 in Fig. 1 b for example), if any such still exists, has, at the time being considered, passed above M. On Fig. 11, such a vertical position is shown in BC.

The volume of filtrate flowing across the horizontal plane through point M between times t and $t + dt$, is equal to $\pi(x^2 - r^2)\, v_z\, \phi\, dt$, r being the radius of the hole, ϕ the porosity, and v_z the vertical velocity, which, in a homogeneous bed, is constant with respect to space and to time. The volume of filtrate that crosses the wall of the hole in the section between the bottom of the bed and the level of point M (section AH with AH = z), between the same times t and $t + dt$, is equal to $2\pi r z\, v_r\, \phi\, dt$, where v_r is the radial velocity at the wall of the hole (v_r, at a given time, can be taken as being substantially constant).

If it is assumed further that v_r is constant with time, the portion AMB of the invasion front is at an equilibrium position, and these two volumes must be equal. It follows:



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$$\pi(x^2 - r^2)\, v_z\, \phi\, dt = 2\pi r z\, v_r\, \phi\, dt \quad . . . . . (1)$$

Hence:

$$x = \sqrt{2rz\frac{v_r}{v_z} + r^2} \quad . . (2)$$

Equation (2) shows that the shape of the invasion front over section AMB is a paraboloid of revolution around the axis of the hole.*

In fact, the radial velocity v_r is not constant, but decreases progressively with time as the mud cake thickness increases. Accordingly, x decreases also with time. In other words, at any given level HM in a bed, the invasion front recedes toward the hole after the instant when the filtrate that had penetrated at level A at time zero has risen to level M**. Up to that time, M had been in a vertical part of the front, moving out from the hole. The evolution of the invasion front at any level in the lower part of a bed is therefore first a progression, then a recession. The higher the level, the later the recession starts, and this up to a distance sufficiently near the top boundary, where filtrate accumulates and where the depth of invasion continues to increase without limit.

If filtration stops completely, all the filtrate eventually will gather along the upper boundary and the invaded condition will disappear elsewhere in the bed.

Field Examples

In addition to their possible interest in drilling and production practice, the above concepts account for the behavior of electrical logs in salt-water-bearing sands of high permeability.

Fig. 12 shows the conventional ES, microlog, and section gage recorded over a sequence of sands, shales, and thin tight streaks. The sands have a high permeability and are all salt-water-bearing. The drilling mud is appreciably fresher than the connate water.

Section A will be examined in detail as an example. This section can be divided into two parts, a and b, according to the resistivity curves and the microlog.

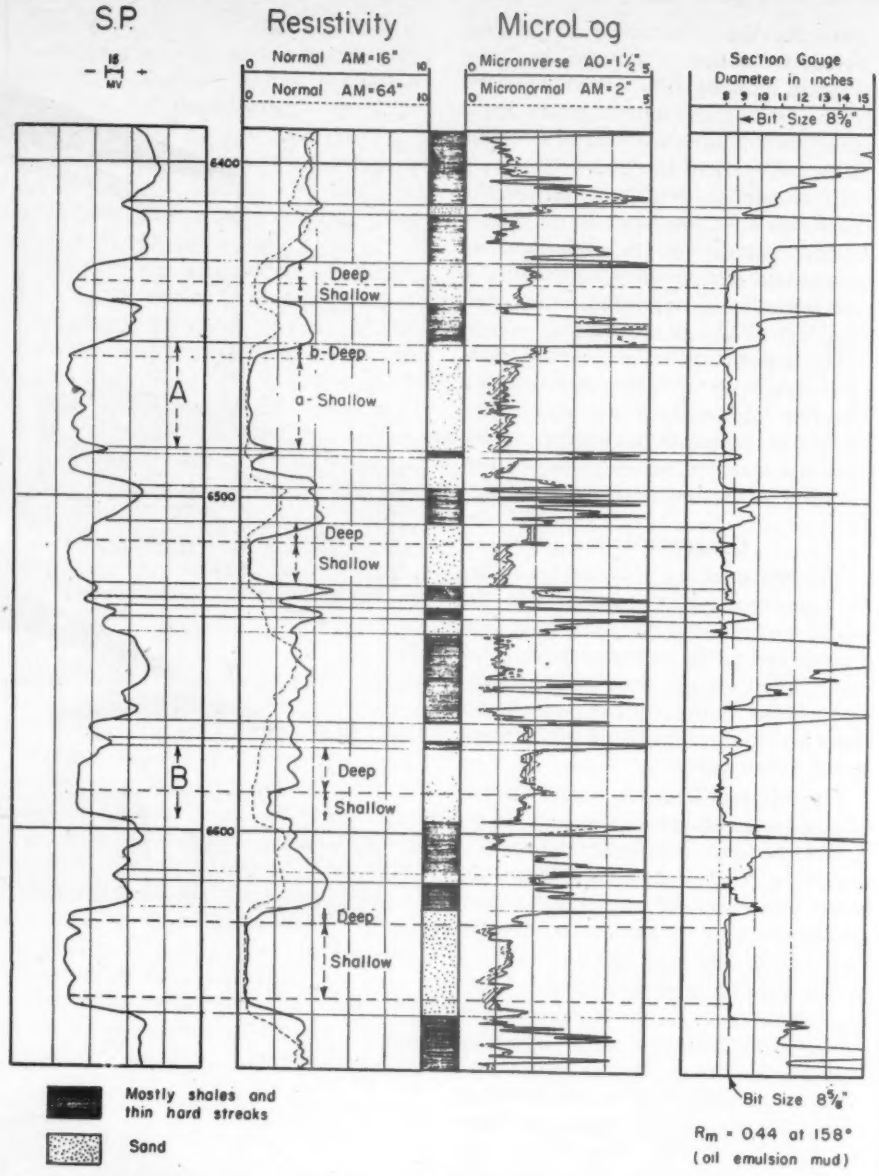

FIG. 12. Example showing effect of convection currents in salt water bearing sands of high permeability: Shallow invasion at bottom and deep invasion at top.

In sub-section a, both short and long normal curves track practically together, which is indicative of a very shallow invasion. On the other hand, the microlog shows a negative separation. In a permeable bed of low resistivity, this means that R_{xo}, resistivity of the formation close to and behind the wall of the hole, is smaller than R_{mc}, the resistivity of the mud cake. If the depth of invasion were at least equal to the average radius of investigation of the microlog (i.e. about 3-in. from the wall), R_{xo} would be approximately equal to the mud filtrate resistivity multiplied by the formation factor, i.e. would be greater than R_{mc}, and a positive separation would be observed. The fact that R_{xo} is smaller than R_{mc} is due to the presence of the uncontaminated zone, whose resistivity is very low (0.4 ohmmeter, according to the normal curves), within the radius of investigation of the microlog, i.e. at very close distance from the wall. The negative separation observed on the microlog therefore confirms that the invasion is very shallow in this sub-section.

In sub-section b, just below the tight adjacent bed, the greater values recorded on both curves indicate a deeper invasion. This is confirmed by the higher values and the positive separation observed on the microlog.

The SP curve and the microlog show that the bed is not homogeneous and contains variable amounts of shale (although the variations on the microlog curves may correspond partly to changes in mud cake thickness). It appears that, despite the presence of interstitial shale, the vertical permeability of the bed is nevertheless great

*Curve AMB is a line of flow, and, accordingly, the filtrate velocity at points along AMB is tangent to this curve. It is thus possible to write for points along AMB:

$$\frac{\partial z}{\partial x} = \frac{v_z}{v_x}$$

v_x being the radial velocity at each point along AMB, which in turn is related to v_r through:

$$\frac{v_x}{v_r} = \frac{r}{x}$$

Hence:

$$\frac{\partial z}{\partial x} = \frac{v_z . x}{v_r\, r}$$

Integrating this equation leads again to equation (2).

**The slope of the tangent to curve AMB at point A is v_z/v_r; this shows that, at the bottom of the bed, the tangent to the curve approaches the vertical with time, or, in other words, that the invasion front approaches the wall of the hole.

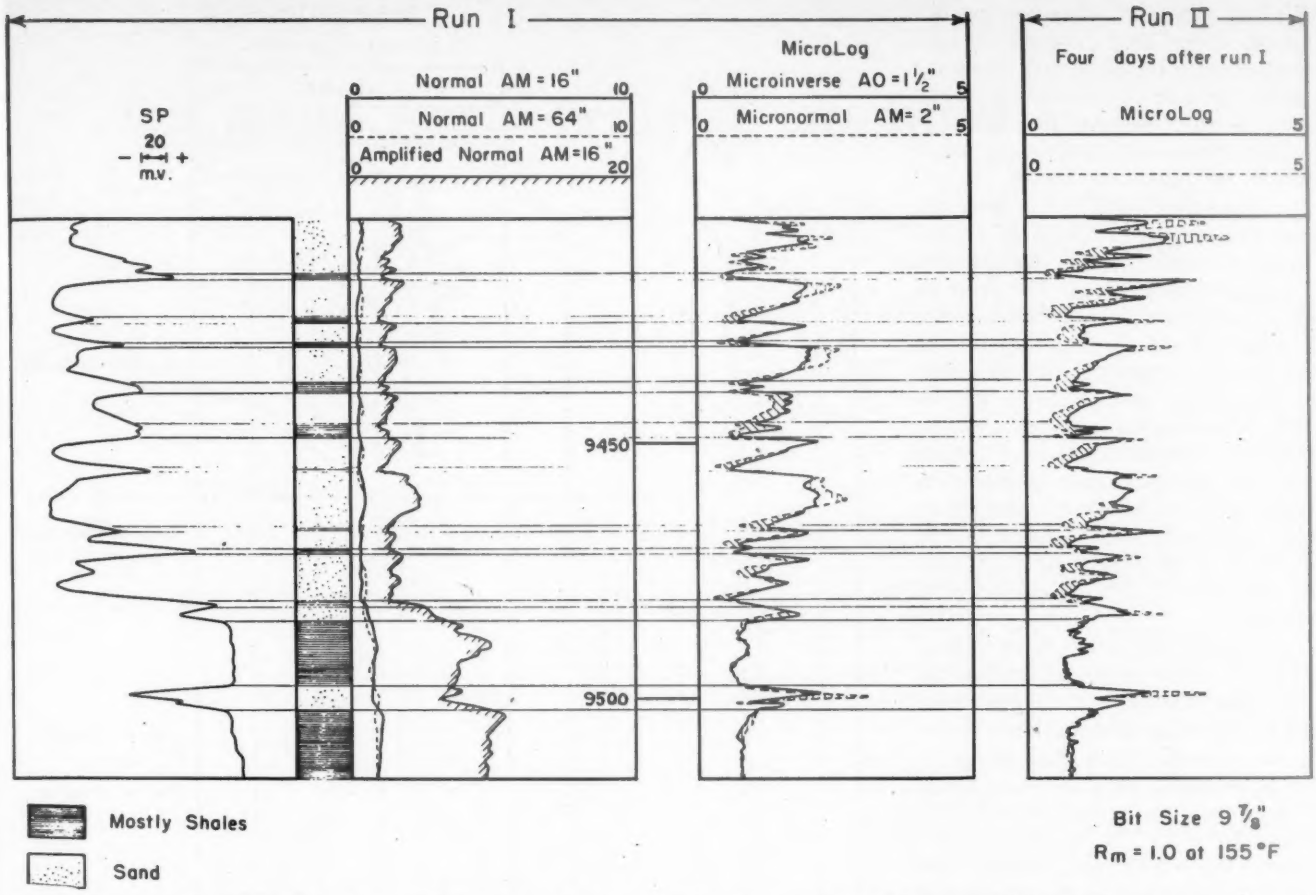

FIG. 13. Example showing effect of convection currents in salt water bearing sands of high permeability: shallow invasion at botton and deep invasion at top.

enough for the convection currents to be appreciable.

Similar considerations apply to the other permeable sections. The feature is slightly different in bed B. The lower part, with shallow invasion, is clearly differentiated from the upper part, with deep invasion; however, in the lower part, the short normal curve stays higher than the long normal, which shows that the invasion is not so shallow as in the case of bed A, section a, for example. Correspondingly, the separation between microlog curves, instead of being negative, is slightly positive.

The section gage log indirectly confirms the existence of convection currents. Considering each individual sand, the log shows that the mud cake thickness has no tendency to increase from the bottom to the top. This indicates that the rate of filtration should be substantially the same at all levels of the same bed. As the porosity is known to be constant on the average, the depth of invasion would be also the same, if there were no convection currents.

Fig. 13 is another example of a similar sequence of formations. The point of interest is that the microlog was recorded twice: In run I, at the same time as the conventional log; in run II, four days later. The comparison of the amplified short normal curve and of the microlog run I again shows the effect of the convection currents on the behavior of the invaded zone. Furthermore, on microlog run II, the amplitudes of the negative separations and their vertical extensions are more accentuated than in run I, whereas the sections with positive separations are narrower. This shows that the invasion front receded between run I and run II, except at a very close distance below the upper boundaries where filtrate continued to accumulate.

Case of Oil Bearing Formations

The mathematical analysis of the problem of invasion in case of oil bearing formations seem to be very involved. The problem, accordingly, was studied only in the laboratory, and with simple equipment. The model consisted of two identical burettes filled with glass beads and water of 1.04 specific gravity. Oil was poured into the burettes from above until about one-half the formation was oil invaded. Then dyed filtrate water of 1.00 specific gravity was introduced in each system through a glass tube. In one burette the tube outlet was in the oil-bearing portion above the oil-water interface, in the other burette the tube outlet was in the water portion.

It was found, in the first case, that the fresh filtrate water sank through the oil to the oil-water interface and floated on the top of the salty formation water without appreciable mixing. In the second case, the fresh water rose through the salty water up to the oil-water interface and concentrated at this level, with some mixing between the fresh and salty water.

This experiment suggests the idea that in a high permeability formation supposed substantially homogeneous, which is oil-bearing at the top and salt-water-bearing at the bottom, the mud filtrate would tend to flow downward in the oil-bearing part and upward in the water-bearing part. This process would create a zone of deep invasion near the oil-water level, whereas invasion would be shallower everywhere else.

The conditions of the laboratory experiments, however, were so different from the actual conditions prevailing in the formations that the above suggestion should be considered with great caution. It is certain, in particular, that the permeability of the formation in the laboratory model was enormous in comparison with the highest permeabilities encountered in practice. Although this circumstance was acceptable for

the investigation of water-bearing formations, it may give a completely false representation of the actual phenomenon in the case of oil-bearing formations, if only because the effect of capillary forces was practically negligible in the laboratory model.

On the other hand, it has been difficult thus far to find definite experimental evidence of the phenomenon on actual electrical logs. The deep invasion zone, if such really exists at the oil-water contact, would have a limited vertical extension and, with the present measuring devices, could not be easily differentiated from the oil-bearing zone. Furthermore, to ascertain from the electrical logs available at present whether invasion is shallow or deep is generally difficult, and even impossible in oil-bearing sections, because the values of R_{xo} and R_t are not very different.

An example is shown, nevertheless, in Fig. 14, which seems to confirm the assumption that filtrate accumulates near the oil-water contact. The log was run in a thick, fairly homogeneous, high permeability sand (porosity about 30 per cent and vertical permeability about 1000 md). The resistivity of the mud was 0.4 at 89 F, much higher than that of the connate water, which was known to be quite salty.

The invasion is extremely shallow over the interval AB where low readings are observed on the two normal curves (about 0.5 ohms). The upper section CD is known as oil-bearing, and corresponds to high resistivity values on both curves (10-15 ohms). In the transition zone BC, intermediate resistivities are observed, with the short normal reading higher than the long normal. It does not seem that the transition is caused by a progressive decrease of water saturation, corresponding to a progressive increase of R_t, since for so high a permeability the oil-water contact should be sharp. The possibility of lithologic variations is also excluded, according to what is known about the formation. As the filtrate is more resistive than the connate water, it is therefore likely that the feature observed in zone BC corresponds to a progressive increase of the depth of the invaded zone, as a result of convection currents, below the oil-water contact.

Whether the invasion is deep or shallow in the oil-bearing zone is difficult to decide from the logs.

The use of new methods such as laterolog and induction log, which have a better resolving power and which furthermore should permit the evaluation of the depth of invasion, perhaps will provide some more accurate data on this phenomenon in oil-bearing formations.

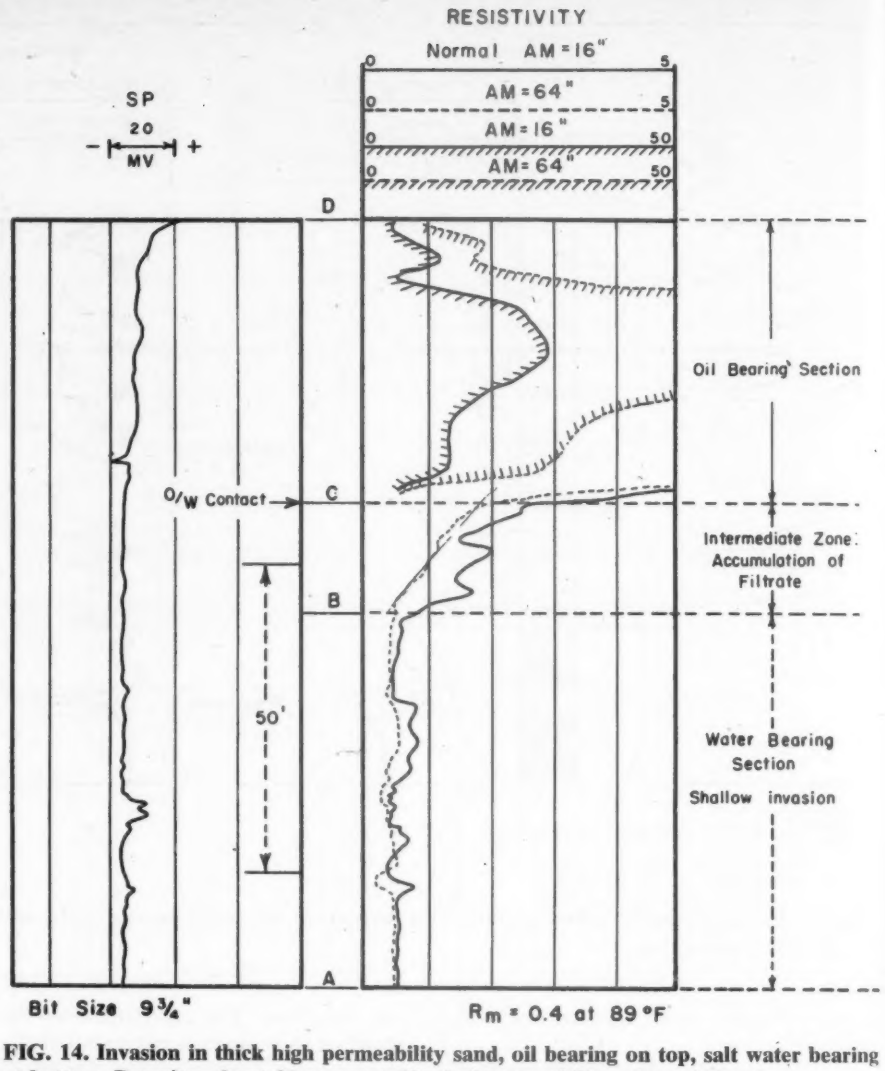

FIG. 14. Invasion in thick high permeability sand, oil bearing on top, salt water bearing at bottom. Porosity: about 30 per cent. Vertical permeability: about 100 md.

It is actually easier for water to flow through a porous diaphragm when this diaphragm is completely filled with water than when it is filled with both oil and water, all other conditions being the same. In the latter case, the water has to displace the oil and its movement is responsive to the effective permeability of the diaphragm to oil, which, of course, is smaller than the single-phase permeability to water, and to the viscosity of the oil, which generally is greater than the viscosity of water.

Accordingly, when mud filtrate penetrates into a formation that is oil-bearing at top and water-bearing at bottom, it may find a greater resistance to flow radially across the oil-bearing pores, than when it descends toward the water table. This consideration would support the hypothesis that mud filtrate tends to flow downward in the oil-bearing part of a permeable bed. It would even seem that this tendency should prevail whatever the permeability of the bed.

All this, of course, is merely speculative and has not been checked by any experiment or theoretical analysis.

Conclusion

1. The hypothesis has been advanced that in salt-water-bearing sands of high permeability, drilled through with comparatively fresh mud, convection currents occur due to the difference in density between mud filtrate and connate water. The effect of these convection currents is to drive mud filtrate toward the upper boundary of the bed, so that the invasion is shallow in the lower part and deep in the upper part.

2. Corresponding laboratory tests have been described, and a computation of the phenomenon discussed. It has been shown that both studies confirm the above hypothesis, and also provide data on the shape of the invasion front, and on its evolution with time.

3. It has been shown that the concept of convection currents accounts for the behavior of the electrical logs run in the formations in question.

4. The investigation of the case of permeable beds containing oil at top and salt-water at bottom is still very

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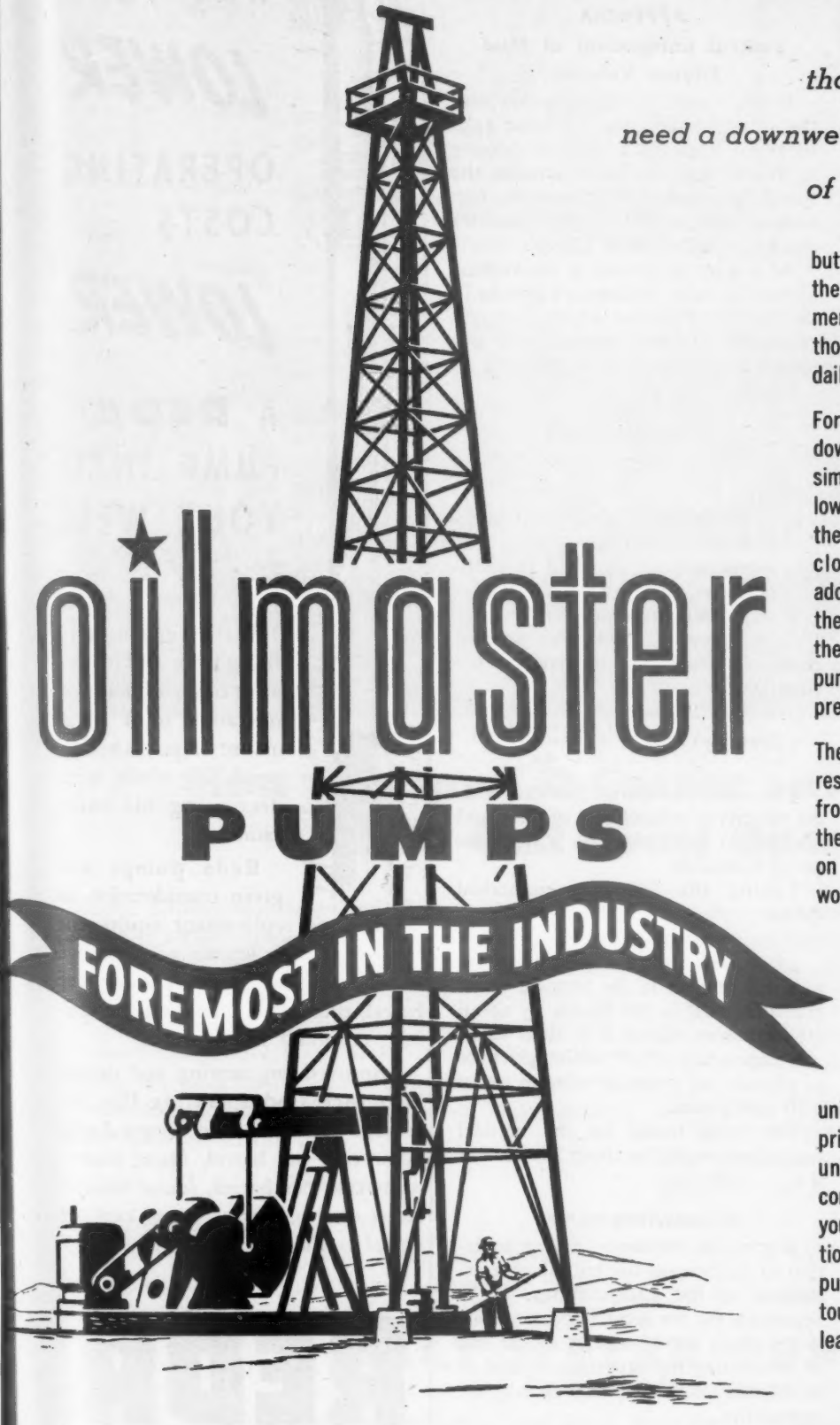

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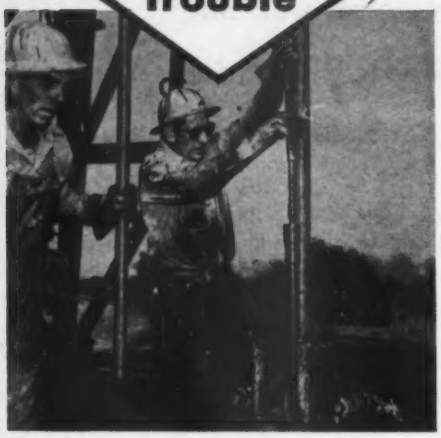

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incomplete. It is, nevertheless, suggested that mud filtrate flows downward in the oil-bearing part and upward in the water-bearing part, thus accumulating around the oil-water contact.

APPENDIX

Vertical Component of Mud Filtrate Velocity

Briefly stated, the theory is that after the filtrate penetrates the mud cake sheath it acquires a vertical velocity v_z due to the difference between the specific gravities of the filtrate and formation waters. The vertical velocity can be evaluated from Darcy's law:

At a point of altitude z, the volume of fluid in cubic centimeters flowing in the vertical direction across 1 square centimeter of cross-sectional area per second is $v_z \phi$, ϕ being the porosity.

Hence:

$$v_z = -\frac{k_z}{\mu\phi} \cdot \frac{\partial p}{\partial z}$$

Where:

k_z = permeability in the vertical direction in darcies,

μ = viscosity of the fluid in centipoises, and

p = pressure in atmospheres

Using practical units, the vertical components will thus be given by the equation:

$$v_z \text{ (feet-day)} = 2.74 \frac{(\rho w - \rho mf)\, k_z}{\phi\mu}$$

This equations shows that the vertical velocity is independent of time, and is constant everywhere in a homogeneous formation.

Taking the following numerical values:

Porosity $\phi = 0.25$,

$\rho w - \rho mf = 0.05$ (this corresponds to a salt content in the connate water exceeding that in the filtrate by about 100,000 ppm, which is a usual case),

Temperature: 200 F, which gives for μ, viscosity of water, a value of about 0.30 centipoises,

The value found for the vertical component would be about 2 ft per day if $k_z = 1000$ md.

Acknowledgments

The writer expresses his appreciation to A. Poupon for his valuable assistance in the computations, to F. Segesman for his most important part in designing the laboratory model and in conducting the experiments, and to M. Martin for his help in preparing the manuscript.

Acknowledgement is also due to J. P. Causse for his mathematical studies involved in the design of the model, and to the oil companies who released the logs for the illustration of this article.

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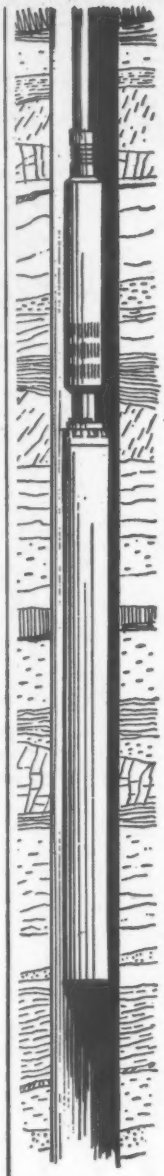

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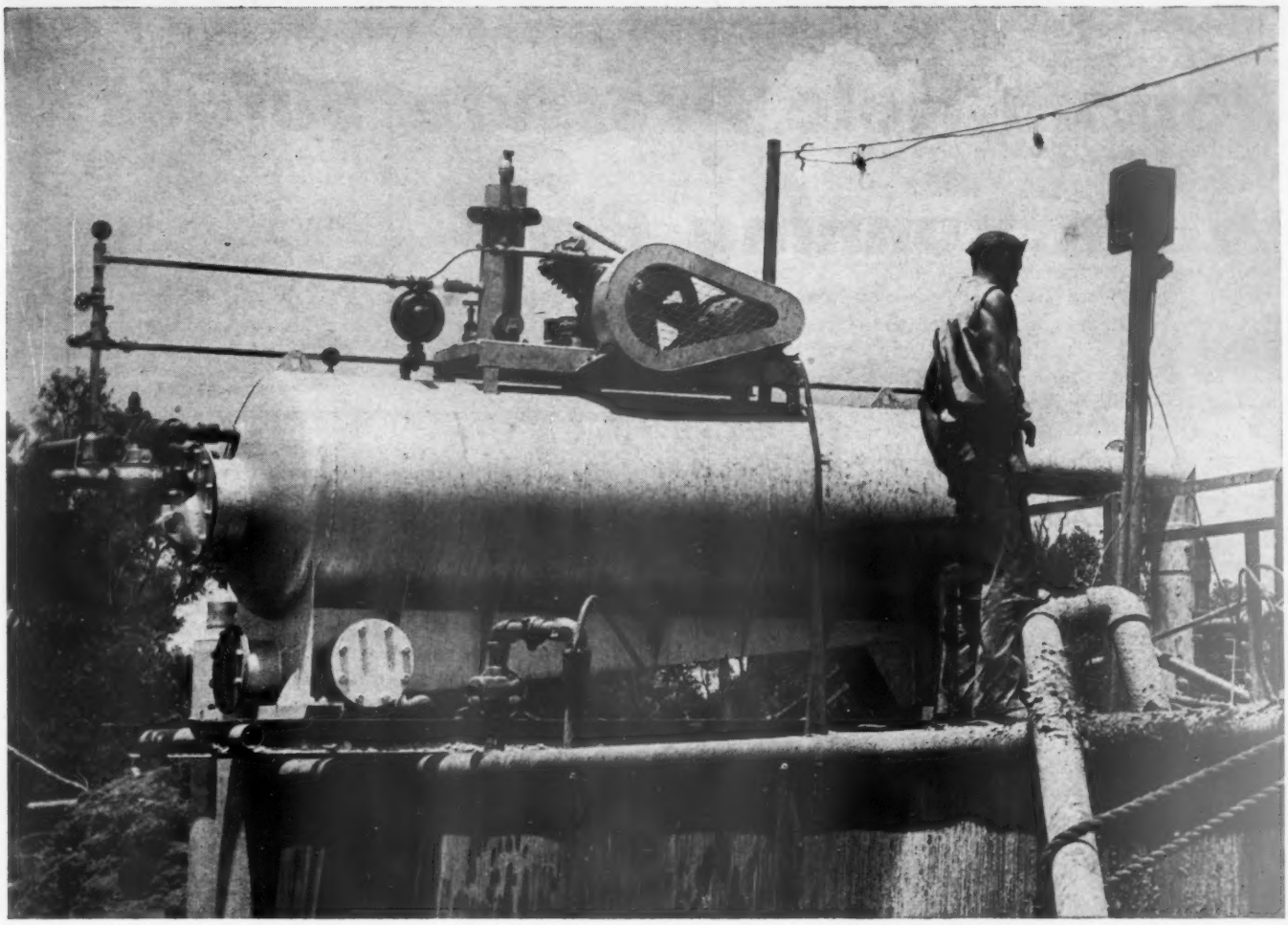

How this mud D-Gasser saved the day for a Gulf Coast Operator*

While drilling near Bay City, Texas, an operator encountered a high pressure salt water flow that caused the mud to become very thick and gas-cut. Weight material was added but with little success—the well soon blew out.

For three days, the operator tried to weight up properly, but due to the frothy, flocculated condition, he could not balance the force for fear the overburden pressure would be exceeded and circulation would be lost. This is another serious problem in this area.

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The operator could then control the mud weight to a few tenths of a pound, and the danger of entrained gas was gone. The operator figures the total rental on the D-Gasser was more than saved the first day it was in use.

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* Name on Request

Bottom-Hole Pressure Surges While Running Pipe

E. H. CLARK, JR.

A method of calculating bottom-hole pressure surges due to movement of tubular goods in a well bore and the use of these values in predicting their effect on further drilling and completion is presented here.

The importance of these pressure surges is pointed out by the fact that, if not controlled, they can lead to blowouts, lost circulation, excessive mud costs, wet cement jobs, high gas-oil ratios through communications, or stuck drill pipe. The importance of pressure surges during casing running is emphasized, since these values are generally considerably higher than those of drill pipe. Recommended methods are presented for controlling both drill pipe and casing pressures at very little cost.

The general conclusions are that drill pipe or casing velocity, acceleration, and deceleration can—*and should be*—minimized without markedly changing drilling time. Through such action the resultant savings in "trouble" costs will pay a thousand times over for the few dollars extra per round trip.

In drilling, mud should be mixed and weighted in such a manner as to maintain the plastic viscosity and yield strength at the lowest possible value consistent with other problems. Also, during casing jobs in "tight holes," particular care must be taken with dropping time, or displacements should be relieved by fill-up devices to prevent the bottom-hole pressure from causing excessive amounts of damage.

As early as 1934, Cannon[1] began the publication of work on the importance of pipe movement, and during subsequent years a number of eminent researchers have contributed additional data on this subject.

As a result of their leadership, our ability to measure mud properties and hole conditions has advanced to the point where prediction of bottom-hole pressure surges by mathematical analysis is no longer an untouchable thing. Granted, there are still many complicating and unknown factors below the surface that make such an analysis far from exacting; but we are, none the less, able to calculate a reasonable approximation to the existing pressure.

The importance of these pressure surges, either during drilling or while running casing, cannot be over emphasized. Almost every phase of drilling and subsequent completion operations is affected in a major manner by their magnitude. One of the most firmly established effects, of course, is the blow-out problem, which in itself is adequate reason for such calculations; but the less spectacular, everyday problems probably outweigh this in their total cash cost. The most important of these, dollars-and-cents wise, is the loss of mud either suddenly (as in lost circulation) or slowly by continuous efflux to extremely permiable sections. While it is true that basically these problems are directly tied in with the geological data of the well bore, it is also true that there are very few natural combinations of geostatic and hydrostatic gradients that cannot be successfully controlled. Goins and Associates[2] brought out this point rather forcefully in their 1951 paper by illustrating adjacent wells—one drilled, using standard practices, with 79 separate losses of circulation, and the other drilled, using pressure-relieving practices, without a single loss. A complete pressure analysis would probably reveal that at least 9 out of 10 cases of mud-loss problems are due not to bad formation, but rather to the effects of man-made deterioration of this formation strength. In other words, nature must provide the powder keg, but generally we are the ones who light the fuse.

Background Formulas

In view of the importance of pressure surges, the factors that go into their calculation should be analyzed to establish a set of formulas by which their magnitudes may be predicted. In developing these formulas, it is necessary to make several assumptions, the most important of which is that the fluid in question and the walls of the hole are incompressible. It is also assumed that the tubing, drill pipe, or casing being run is at all times concentric with the drilled hole, and that the hole is round and to gage for its full length.

Basically, the pressures created fall well within the normal concept of hydraulics, provided the movement of the boundary areas as well as the movement of the fluid in question are properly accounted. It must also be remembered that the action of running or removing tubular goods is not a steady operation, but an intermittent procedure, causing in all cases acceleration and deceleration pressures to enter into the picture.

The inclusion of acceleration effects is not so complicating as it would appear at first glance, since these effects can be calculated separately from the hydraulic frictional losses occurring at any given value of fluid velocity. When taken over the whole cycle, the acceleration pressures do not affect the net energy losses of the system, because the entire input of acceleration energy is removed during the deceleration portion of the cycle. This means that the net fluid motion as governed by the path of minimum expenditure of en-

The Author

E. H. Clark, Jr., received degrees of Bachelor of Science and Master of Science in mechanical engineering from the California Institute of Technology. Following graduation he became associated with Baker Oil Tools, Inc., Los Angeles, California, in 1947. His duties with Baker have varied from production engineering to research.

Recalled to active duty during the first part of the Korean War, Clark returned to Baker after completion of his service where he was soon appointed to his present position of assistant chief research and development engineer. Recently, he has been working to a large extent on automatic casing filling devices and their effect on the ultimate completion of the well.

ergy, is not affected by the acceleration values, but by the hydraulic friction losses alone. In other words, the effects of acceleration and deceleration may be calculated as separate effects over and above the classical steady-flow hydraulics.

Dunn, Nuss, and Beck,[3] in their work with the Bingham equation, have established and field-tested a formula giving the frictional pressure drop for plastic fluids in steady laminar flow within fixed boundaries. This equation, as rearranged by Ormsby[4] into commoner field units, is given in Formula 1.

Formula 1—Friction Drop in Laminar Flow for Plastic Fluids

$$P = \frac{lt_Y}{225\,D} + \frac{nlV}{1500\,D^2}$$

P = pressure drop in psi over the length being calculated.

l = total length in feet of the diameter being considered.

t_Y = yield point of the mud in lb per 100 sq ft.

n = plastic viscosity of the mud in Centipoise.

V = mean fluid velocity of the mud in ft per sec.

D = { pipe ID in inches for internal flow, or bit size minus pipe OD in inches for annular flow.

In the turbulent flow range, several formulas are available, each varying slightly in its empirical constants. R. J. S. Pigott's[5] formula for pressure loss between two points in steady turbulent flow with fixed boundaries is given by Formula 2.

Formula 2—Friction Drop in Turbulent Flow

$$P = \frac{0.001296 f l \rho V^2}{D}$$

f = Pigott friction factor from Fig. 1.

ρ = mud weight in lb per cu ft (7.48 × lb per gal)

The friction factor of this equation is a function of the Reynolds number, as presented in Fig. 1, which was plotted by Pigott through analysis of a large number of empirical test results. The value of Reynolds number for this chart may be calculated from Formula 3.

Formula 3—Reynolds Number in Turbulent Fow

$$R = \frac{396 D \rho V}{n}$$

R = appropriate Reynolds number in turbulent flow.

This formula uses the more readily available plastic viscosity as suggested by the empirical results of Dunn, Nuss, and Beck, rather than "turbulent viscosity" as used by Pigott, although either calculates out to approximately the same number.

To find the approximate lower critical value of velocity at which the flow will change from laminar to turbulent,

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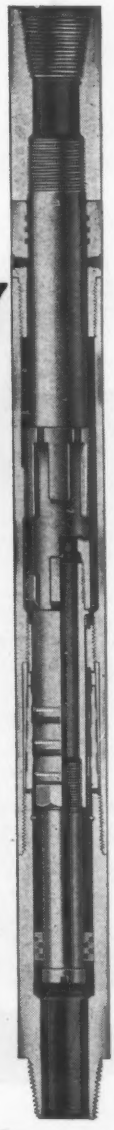

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Formula 4 as given by Dunn, Nuss, and Beck[3] can be used. (This formula uses a more exact form for Reynolds number, based on the Bingham equation rather than on the approximate form given in Formula 3, which is valid only after turbulent flow has been well established.)

Formula 4—Approximate Lower Critical Velocity based on R = 2000 in Laminar Flow

$$V_{LC} = \frac{8.07n + 8.07\sqrt{n^2 + 1.65\rho t_Y D^2}}{\rho D}$$

V_{LC} = lower critical fluid velocity in ft per sec.

n = plastic viscosity of the mud in Centipoise.

ρ = mud weight in lb per cu ft (7.48 × lb per gal.)

t_Y = yield point of the mud in lb per 100 sq ft.

D = { pipe ID in inches for internal flow, or bit size minus pipe OD in inches for annular flow.

Actually, however, it is considerably more accurate to establish the critical velocity by plotting the pressure drops given from Formula 1 against those given by Formula 2 and using the intersection of the two curves as the critical velocity.

In general, these calculations at different velocities are required for other portions of the problem and present little additional work. Formulas 1 through 4 are applicable to either annular or internal flow, provided the concept of hydraulic radius is applied to the diameter term as indicated in the formula nomenclature. The difference in answers between this approach and a rigorous intergration solution does not warrant the use of a more complicated exact value. It should be pointed out, however, that diameters cannot be averaged. Where different diameters exist, the length of each must be calculated separately, as diameters enter all equations on an exponential basis.

Effect of Pipe Motion

In using these formulas it must be remembered that either one or both of the confining walls of the hole are in motion. To gather a physical concept of how this affects the pressure, let us assume a hypothetical case of two open-ended, concentric pipes placed vertically in the middle of the ocean. If the outer pipe were held stationary and the inner pipe lowered, it could be noted that fluid would cling to the inner pipe and be carried down and out the bottom of the system, thereby lowering the fluid level at the surface. Conversely, if the inner pipe were brought upward, clinging fluid would draw in water at the bottom and cause

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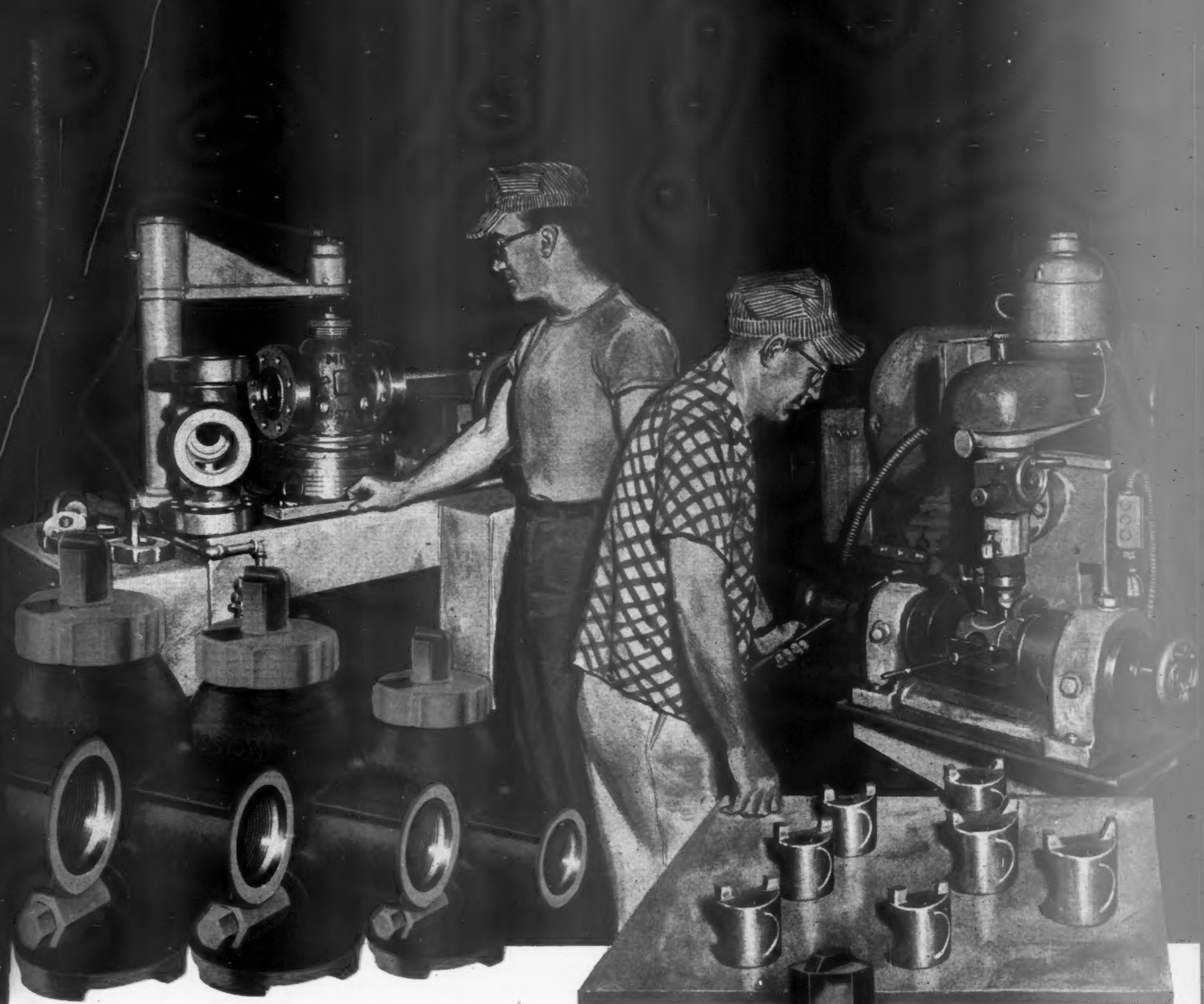

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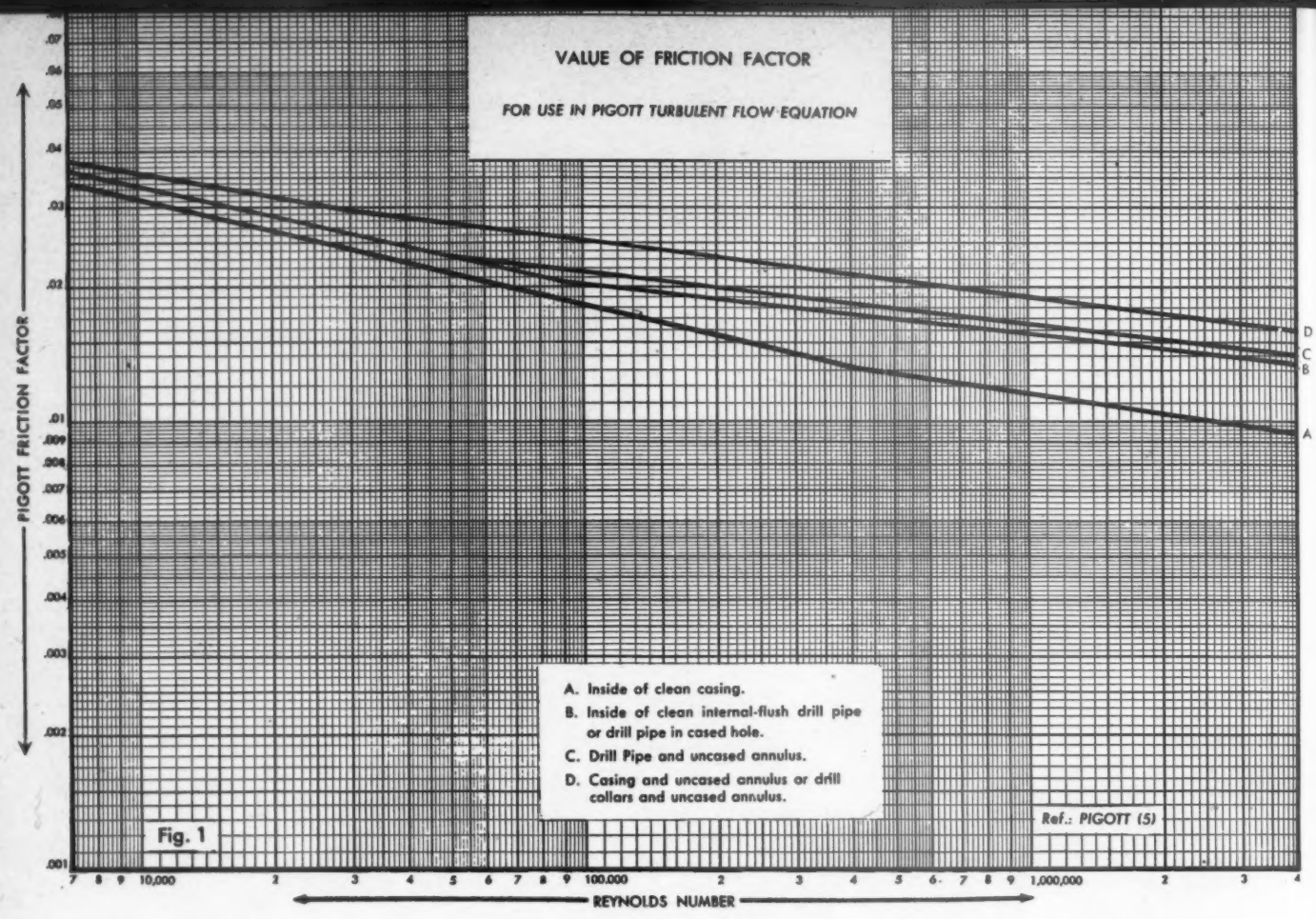
VALUE OF FRICTION FACTOR
FOR USE IN PIGOTT TURBULENT FLOW EQUATION
PIGOTT FRICTION FACTOR
REYNOLDS NUMBER
A. Inside of clean casing.
B. Inside of clean internal-flush drill pipe or drill pipe in cased hole.
C. Drill Pipe and uncased annulus.
D. Casing and uncased annulus or drill collars and uncased annulus.
Ref.: PIGOTT (5)
Fig. 1

FIG. 1.

it to spill over at the top. The same action in miniature is observed when a fishing line is rapidly withdrawn from the water—the water clinging to the line can actually be seen in that it causes a small mound of water to rise up when the line breaks through the surface.

This effect, as first pointed out by Cardwell,[6] is shown diagrammatically in Fig. 2 and, if we give a mathematical shape to these curves, they can be integrated to establish a value for the mean velocity at which fluid is carried either up or down. The actual magnitude of this "clinging velocity" on the inside of the pipe turns out to be simply the pipe velocity in either turbulent or laminar flow. In the annular section, however, it is a function of the radius ratio in both types of flow as well as a function of friction factor in turbulent flow.

The mean values shown in Fig. 2 represent quantities typical for the most common drill pipe and casing programs. While it is true that these values are not exact for all cases (particularly in turbulent flow, where two variables must be averaged), the use of these approximations is recommended rather than the exact formulas, since the low values of error do not warrant the trial-and-error solution involved in the exact case. The values shown for turbulent flow are lower than those for laminar flow, because the eddying effect tends to swirl the clinging fluid out into the stream and equalize its velocity.

If a closed bottom and fluid displacement are now added to the hypothetical bottomless case previously mentioned, we have an actual velocity distribution as shown in Fig. 3. Here the net area must equal the observed displacement rates relative to the earth, i.e., Qa in the annulus, or Qp in the pipe. Although the slopes adjacent to the pipe or the wall will vary between laminar and turbulent flow, the schematic picture of Fig. 3 is the same for either.

A further analysis of the formulas for the actual velocity shown in Fig. 3 reveals that it consists of two mathematical components: The velocity that would be driven up the annulus by the existing bottomhole pressure with the pipe stationary, less the velocity carried back down by the clinging to the pipe. This knowledge becomes very useful when it is realized that the bottom-hole pressure can then be calculated under the simple hydraulic Formulas 1 through 4, provided the equivalent velocity, composed of observed displacements plus the clinging velocity, is used. The values of equivalent velocity for the different conditions are given by Formulas 5, 6, and 7, thus providing a means for claculating pressure drops inside or outside the pipe for a given internal or external displacement.

Formula 5—Equivalent Velocity for Laminar Annulus Flow

$$V = \frac{Q_A}{A_A} + \begin{cases} .46\ V_P \text{ (for casing)} \\ \text{or} \\ .39\ V_P \text{ (for drill pipe)} \end{cases}$$

Formula 6—Equivalent Velocity for Turbulent Annulus Flow

$$V = \frac{Q_A}{A_A} + \begin{cases} .181\ V_P \text{ (for casing)} \\ \text{or} \\ .166\ V_P \text{ (for drill pipe)} \end{cases}$$

Formula 7—Equivalent Velocity for either laminar or turbulent flow inside pipe

$$V = -\frac{Q_P}{A_P} + V_P$$

where:

V = equivalent velocity for use in Formulas 1, 2, or 3, or for comparison with Formula 4.
Q_A = observed mean annulus displacement rate in cu ft per sec.
Q_P = observed mean internal displacement rate in cu ft per sec.
A_A = area in sq ft of the annulus alongside the diameter being considered.
A_P = area in sq ft of the internal section being considered.
V_P = velocity of the pipe in ft per sec.

Note: Values are positive when moving down with respect to the earth.

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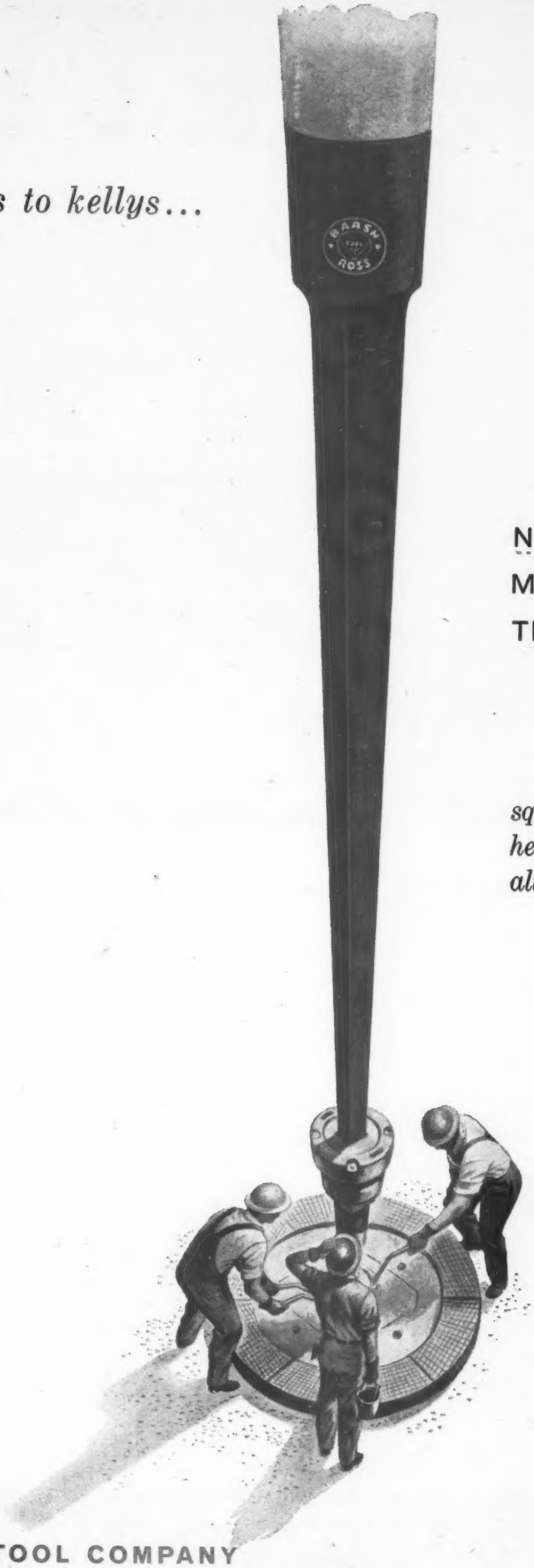

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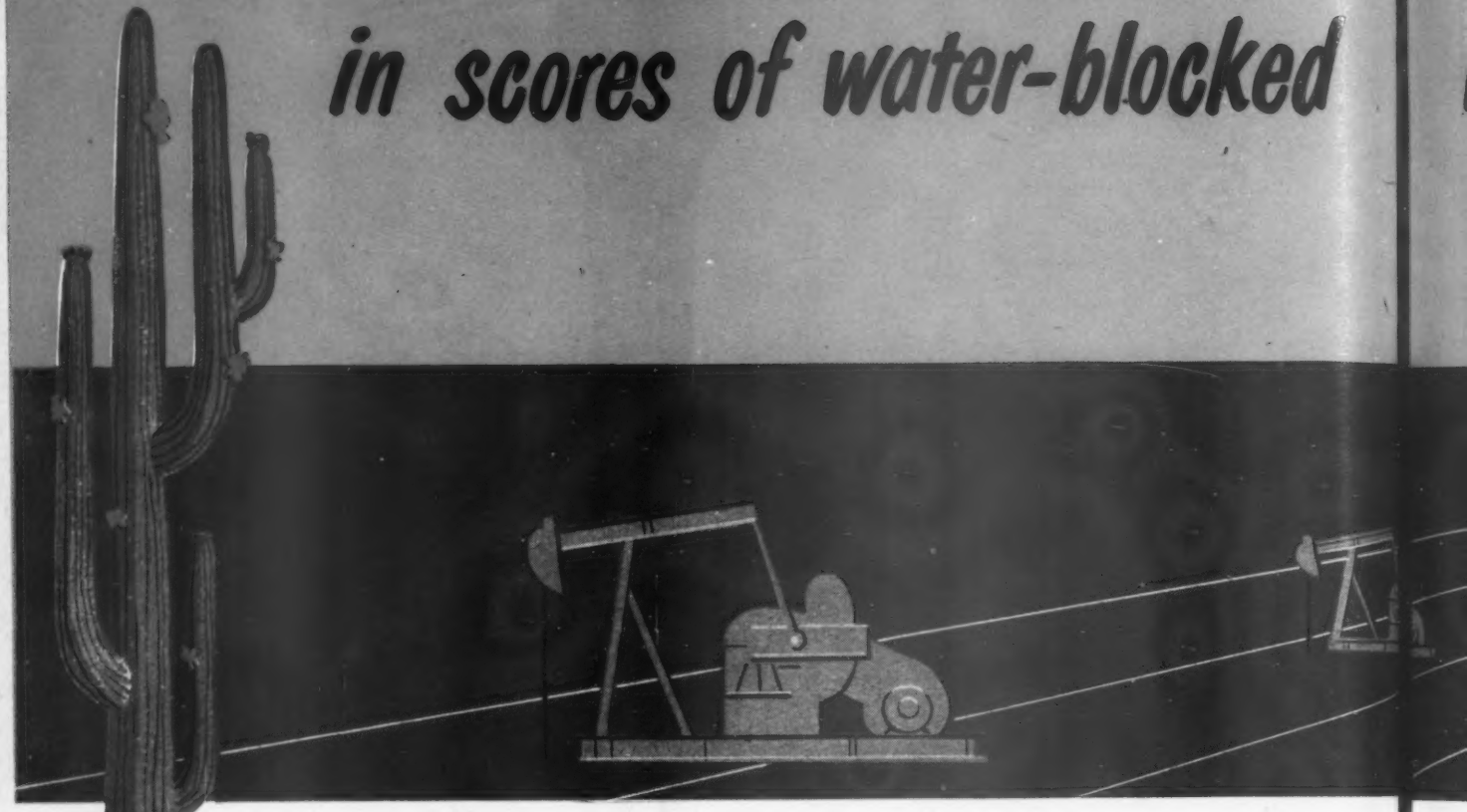

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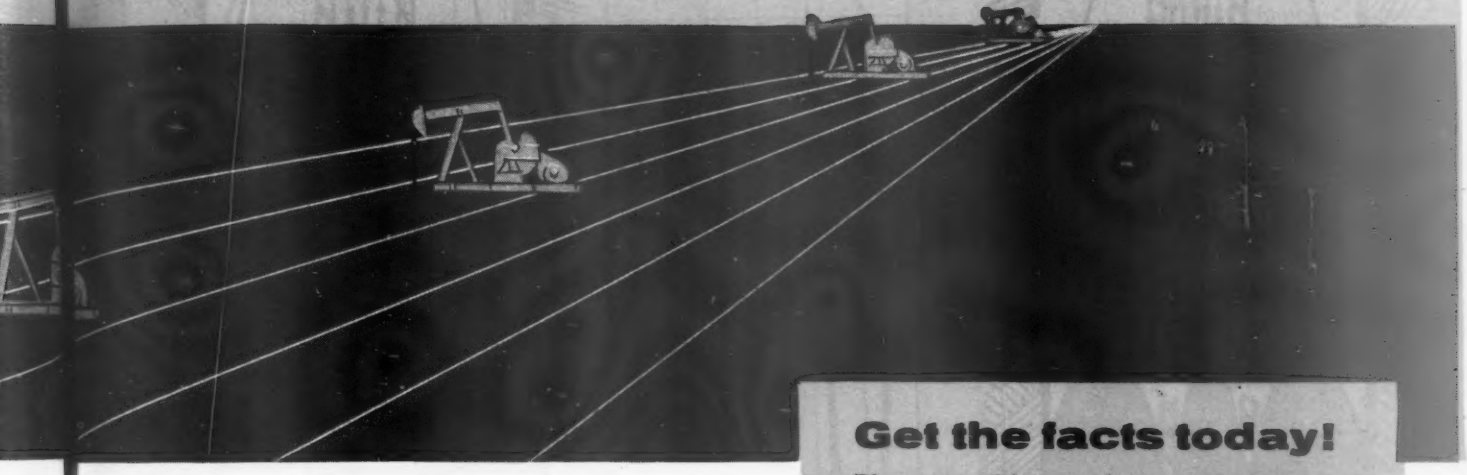

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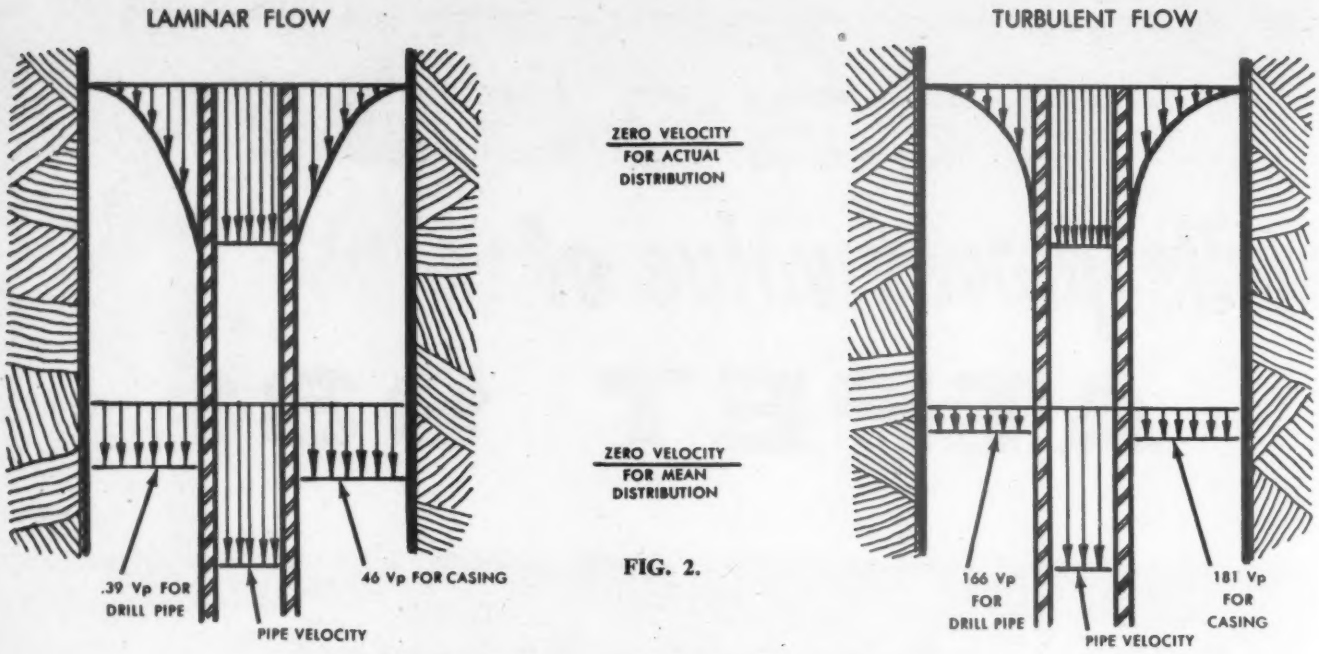


FIG. 2.

Velocity distribution and mean velocity for "clinging" velocity due to moving boundaries in bottomless hole.

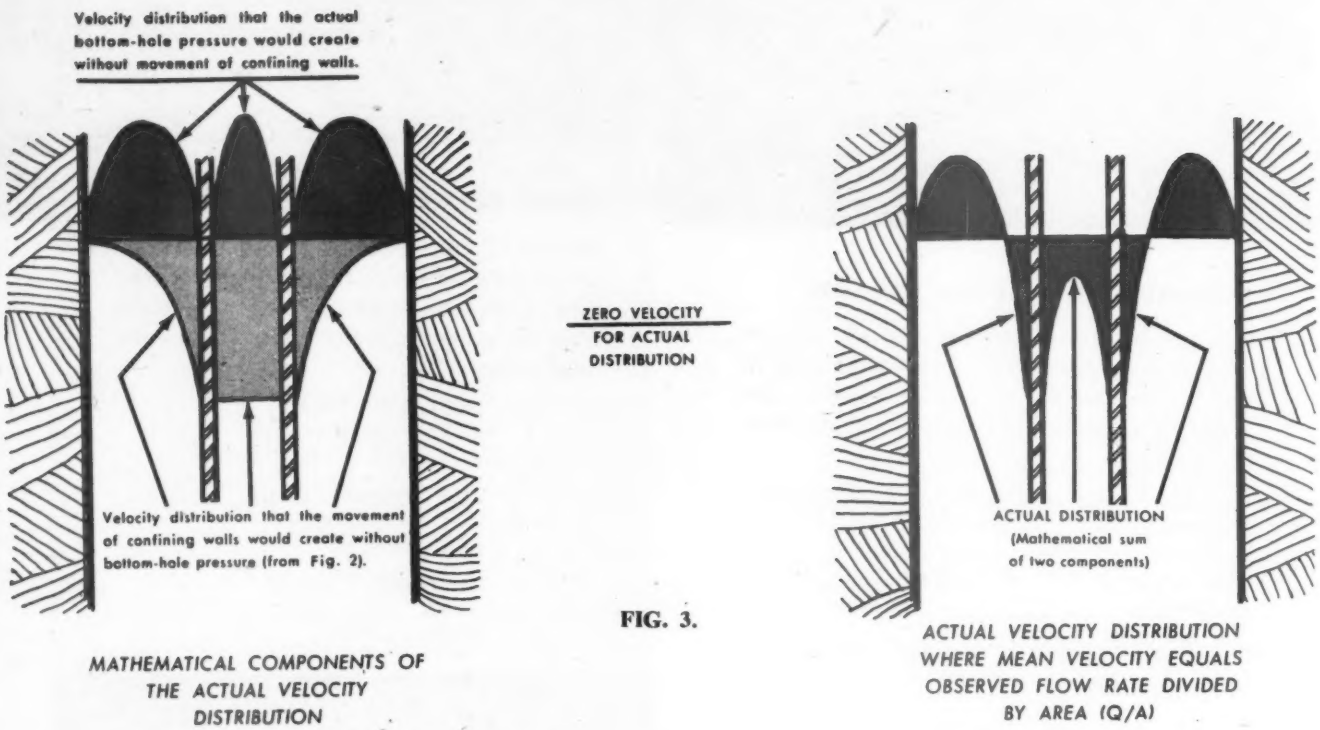

Velocity distribution that the actual bottom-hole pressure would create without movement of confining walls.
Velocity distribution that the movement of confining walls would create without bottom-hole pressure (from Fig. 2).
ZERO VELOCITY
FOR ACTUAL
DISTRIBUTION
ACTUAL DISTRIBUTION
(Mathematical sum
of two components)

FIG. 3.

MATHEMATICAL COMPONENTS OF THE ACTUAL VELOCITY DISTRIBUTION

ACTUAL VELOCITY DISTRIBUTION WHERE MEAN VELOCITY EQUALS OBSERVED FLOW RATE DIVIDED BY AREA (Q/A)

Actual velocity distribution and its components when bottom of hole and displacement are added to conditions of Fig. 2.

Calculation of Per Cent Fill

As the bottom-hole pressure must be the same regardless of whether it is calculated from pressure drops inside or from pressure drops in the annular section, it is possible to equate the bottom-hole pressure caused by fluid movement on the inside of the pipe to the bottom-hole pressure caused by fluid movement in the annulus. After adding an appropriate term for the loss of pressure due to dry pipe, a series of trial-and-error calculations similar to those proposed by Ormsby[4] will establish the per cent fill that would exist under a given set of conditions. This is a rather involved process, particularly in view of the fact that the trial-and-error calculations required even for open-ended pipe are further complicated under actual conditions by head losses across jets or jet bits or through bottom-filling devices in casing.

There is also the complication that generally the annular section and the internal section break into turbulent flow at different pipe-dropping rates, thus requiring trials both in laminar and in turbulent flow. As a result, it is definitely more convenient to calculate the bottom-hole pressure for a series of assumed displacements and then to

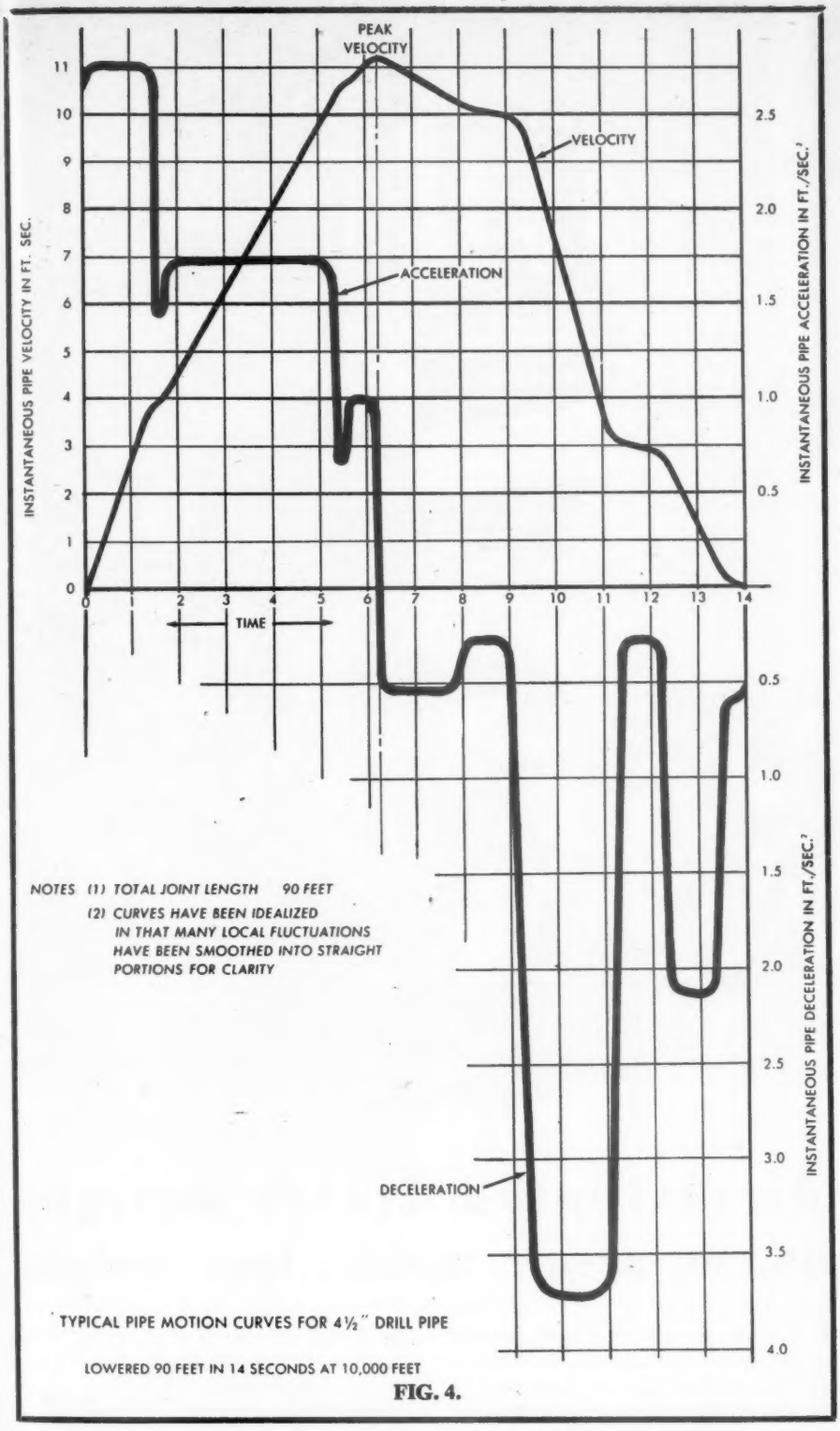

PEAK VELOCITY
VELOCITY
ACCELERATION
DECELERATION
TIME
INSTANTANEOUS PIPE VELOCITY IN FT. SEC.
INSTANTANEOUS PIPE ACCELERATION IN FT./SEC.²
INSTANTANEOUS PIPE DECELERATION IN FT./SEC.²
NOTES (1) TOTAL JOINT LENGTH 90 FEET
(2) CURVES HAVE BEEN IDEALIZED IN THAT MANY LOCAL FLUCTUATIONS HAVE BEEN SMOOTHED INTO STRAIGHT PORTIONS FOR CLARITY
TYPICAL PIPE MOTION CURVES FOR 4½" DRILL PIPE
LOWERED 90 FEET IN 14 SECONDS AT 10,000 FEET

FIG. 4.

pick the proper pressure by observing the flow line returns, rather than to calculate the division of fluid. Since the annulus is generally full, it is easier to measure the volume of fluid coming up by this means than it is to determine the location of the fluid on the inside of the pipe. Calculations to predict the division of the fluid are generally useful only to manufacturers of bottom-filling devices, research people, or, to a certain extent, to jet bit manufacturers designing orifices for critical pressure areas.

Acceleration Pressure

The entire foregoing analysis of pressure due to fluid movement has assumed an unchanging flow to exist with respect to time. In view of the intermittent nature of the pipe operation, however, this is not the case. During the dropping cycle, the pipe goes from zero velocity to a peak velocity and then returns to a stop. Since the pipe motion causes the fluid motion, the fluid must also start from rest, accelerate to a peak value, and then return to rest. This means there must be acceleration and deceleration pressures created to get the changing picture described by the hydraulic flow previously calculated. The value of these acceleration pressures between any two points is given by Formula 8, which was derived from the basic definition of fluid acceleration.

Formula 8—Pressure required to change Fluid Rate of Flow

$$P = -0.0002155 \frac{\rho l}{A} \frac{dQ}{dt}$$

P = pressure drop in psi over the length being calculated.
ρ = mud weight in lb per cu ft (7.48 × lb per gal.)
l = total length in feet of the diameter being considered.
A = area in sq ft of the section being considered.
$\frac{dQ}{dt}$ = rate of change or acceleration of mean volumetric flow in cu ft per sec per sec.

When it is realized that, in a 10,000-ft well it is necessary to set some 25,000 to 40,000 lb of fluid in motion in order to get *any* displacement at the surface, it is easy to realize why acceleration pressures can rise very high and often reach higher values than the instantaneous frictional losses.

Conversion Into Measurable Values

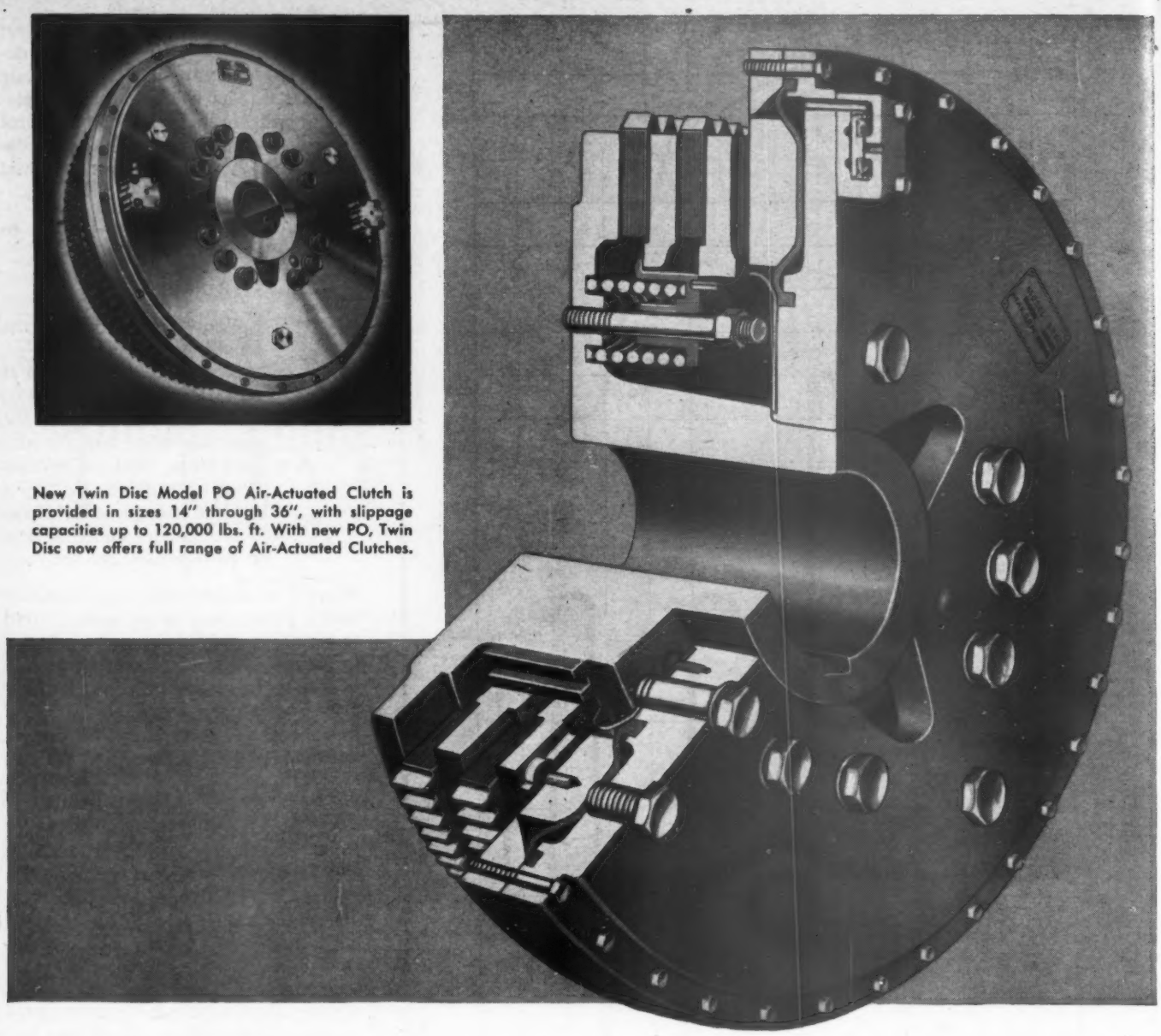
The foregoing formulas are somewhat cumbersome to use because the fluid motion variables are difficult to measure, and should be converted to the more available values of pipe velocity and acceleration. For floating in an incompressible fluid, this relationship is quite simple in that the instantaneous annulus displacement equals the external area of the pipe times the instantaneous pipe velocity. For later convenience, this may be written (as in Formula 9) in terms of the total displacement divided by the joint length.

Formula 9—Observed Annulus Flow Rate as a function of Pipe Velocity for Full Displacement

$$Q_A = -V_P \times \frac{S_{JT}}{L_{JT}}$$

Q_A = observed mean annulus displacement rate in cu ft per sec.
V_P = velocity of the pipe in ft per sec.
S_{JT} = total volume in cu ft displaced up the annulus for the joint being considered.
L_{JT} = total length in feet of the joint being considered.

When no float device is included in the well equipment and the fluid is allowed to seek its own path of minimum energy loss, the instantaneous per cent fill becomes a function of the pipe



New Twin Disc Model PO Air-Actuated Clutch is provided in sizes 14" through 36", with slippage capacities up to 120,000 lbs. ft. With new PO, Twin Disc now offers full range of Air-Actuated Clutches.

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4. *Faster, smoother operation under all working conditions; no seal drag.*

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6. *Long, trouble-free operating life, with extra-large passages from cored back plate providing "air-flow" cooling to the diaphragm insulator plate, springs, and driving plates.*

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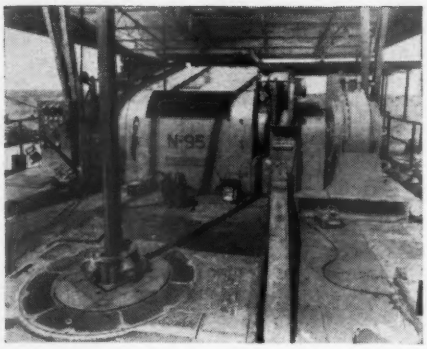
Write today to Twin Disc Clutch Company, Racine, Wisconsin, and request Bulletin 304 for full information, or call Factory Branch at Dallas (Riverside 3014), or Tulsa (4-1578), or Los Angeles (Logan 8-3309).

Air-Actuated Clutches prove adaptability in the oilfields



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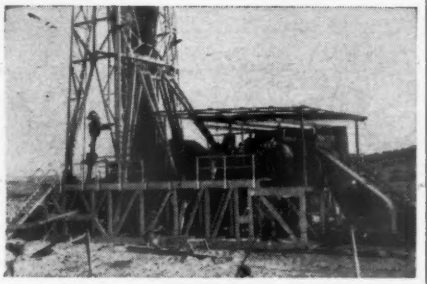

Three Twin Disc Air-Actuated Clutches are used for high torque at low speeds on this Emsco GB-800 Drilling Rig. Twin Disc Air-Actuated Clutches include 3-plate 18" on rotary table, 3-plate 27" on high drum, and 3-plate 24" as master clutches.

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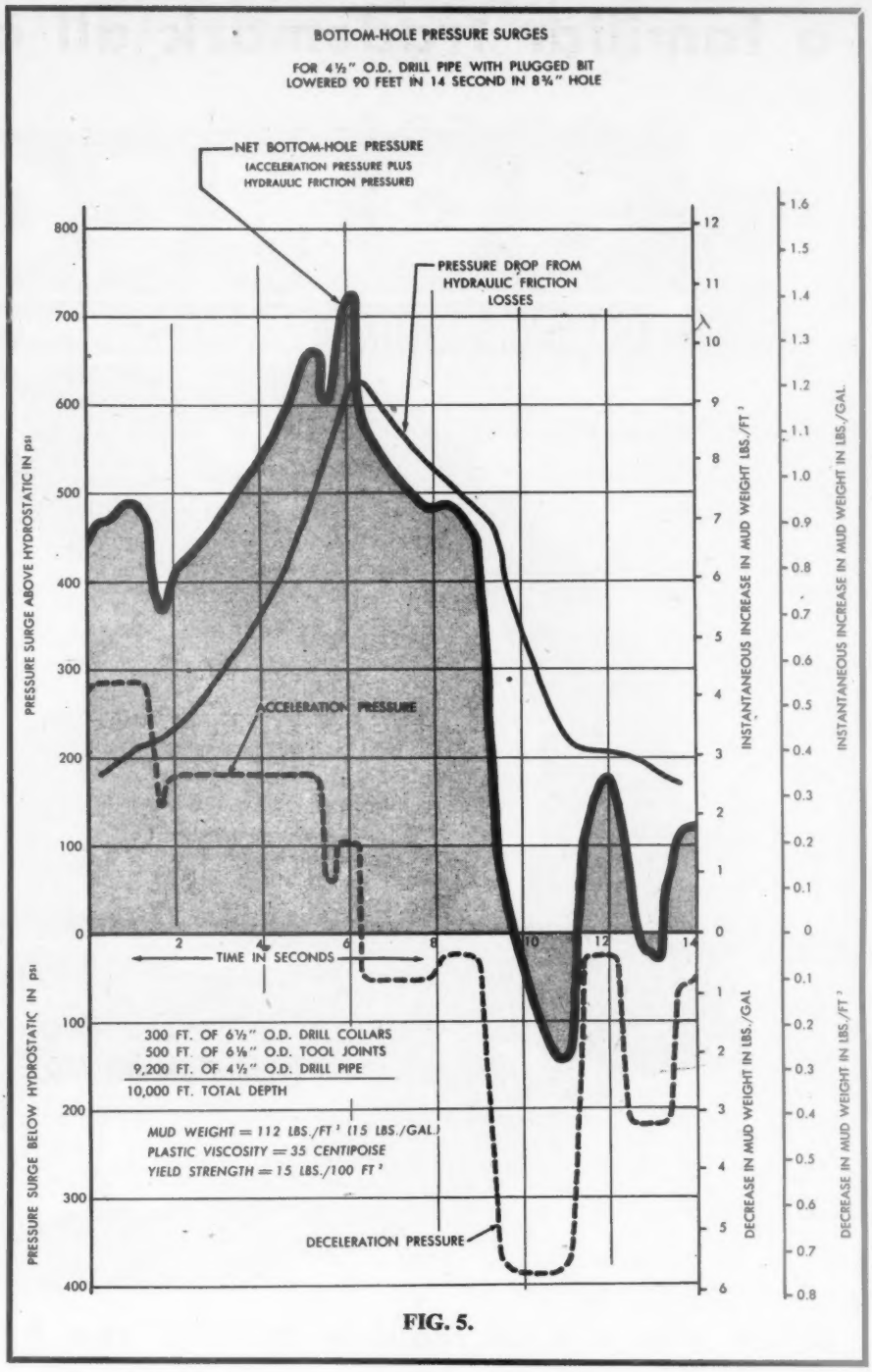
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PRESSURE DROP FROM HYDRAULIC FRICTION LOSSES
ACCELERATION PRESSURE
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PRESSURE SURGE ABOVE HYDROSTATIC IN psi
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INSTANTANEOUS INCREASE IN MUD WEIGHT IN LBS./GAL.
DECREASE IN MUD WEIGHT IN LBS./GAL
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TIME IN SECONDS
300 FT. OF 6½" O.D. DRILL COLLARS
500 FT. OF 6⅛" O.D. TOOL JOINTS
9,200 FT. OF 4½" O.D. DRILL PIPE
10,000 FT. TOTAL DEPTH
MUD WEIGHT = 112 LBS./FT³ (15 LBS./GAL.)
PLASTIC VISCOSITY = 35 CENTIPOISE
YIELD STRENGTH = 15 LBS./100 FT²

FIG. 5.

velocity, particularly where either the annulus or the internal section of the pipe breaks into turbulent flow, and Formula 9 is not strictly true.

The exact relationship must be established by a trial-and-error solution of the per cent fill at each velocity. The average per cent fill, however, can be observed empirically (assuming no fluid loss) through observing the pit displacement. (The annulus *must be full* at the instant of drop, if flow-line returns are to be used.)

Except for short intervals, where either the annulus or the pipe section is in turbulent flow and the other is not, the average value obained from Formula 9 does not deviate too far from the trial-and-error actual value. Because of its ease of use, therefore, this equation is recommended even for open-ended pipe.

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Where enlarged diameters exist on a string of pipe, displacements over and above the displacements observed at the surface must exist at these points. This is obviously true, since, as the projection moves down, there must be a local fluid movement from in front of the projection to fill the void created behind it. The value of this local displacement is equal to the area of the projection times the pipe velocity. The general term of displacement at any

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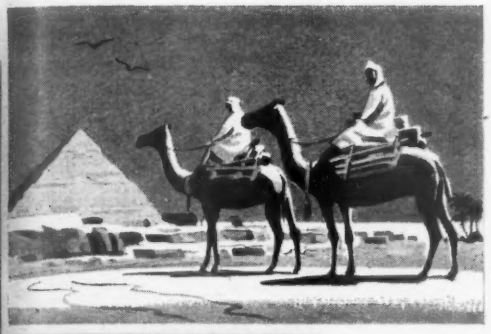

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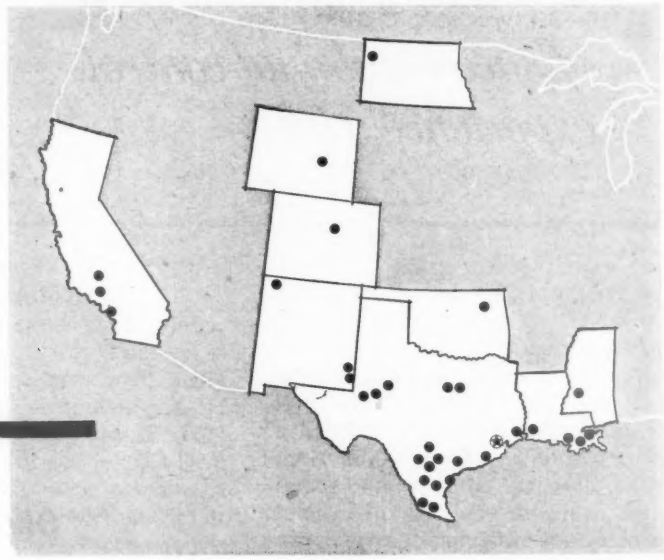

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point in the string would be given by Formula 10, which reduces to Formula 9 when calculating the basic pipe section.

Formula 10—General Annulus Flow Rate as a function of pipe velocity

$$Q_G = Q_A + Q_L$$
$$= -V_P\left(\frac{S_{JT}}{L_{JT}} + A_{PR}\right)$$

Q_G = mean displacement rate in cu ft per sec at any given point in the annulus.
Q_A = observed mean annulus displacement rate in cu ft per sec.
Q_L = local annulus displacement rate in cu ft per sec.
V_P = velocity of the pipe in ft per sec.
S_{JT} = total volume in cu ft displaced up the annulus for the joint being considered.
L_{JT} = total length in feet of the joint being considered.
A_{PR} = area in sq ft that projects outside the basic pipe size on the section being considered. (This equals the area of the enlarged diameter being considered minus the basic area of the OD of the pipe.)

A simple differentiation of this displacement rate will give the acceleration of fluid flow in the measurable terms of pipe acceleration as shown in Formula 11.

Formula 11—General Equation for Rate of Change of Annulus Flow

$$\frac{dQ_G}{dt} = -a_P\left(\frac{S_{JT}}{L_{JT}} + A_{PR}\right)$$

$\frac{dQ_G}{dt}$ = acceleration of annulus flow rate at any point in the annulus in cu ft per sec per sec.
a_P = pipe acceleration in ft per sec per sec.

Completed Formulas for Analyzing Annulus Flow

It is now possible to write each of the flow equations in its final form, involving only items that can be directly measured. Formula 12 gives the loss of pressure due to laminar flow at any given value of pipe velocity.

Formula 13 gives the value of Reynolds number that should be used to find the turbulent friction factor f. *(This value is only an approximation. It is sufficiently accurate for finding the friction factor, but should not be used for critical velocity.)*

Formula 14 gives the loss of pressure due to turbulent flow at any given value of pipe velocity, and Formula 15 gives the value of the acceleration pressure as a function of the pipe acceleration at any given time. (In these formulas, all values are positive when movement is down with respect to the earth.)

Formula 12—General Equation of Hydraulic Pressure Drop for Laminar Annulus Flow

$$P = \frac{l\,t_Y}{225\,D} + \frac{n\,l\,V_P}{1500\,D^2}\left[\frac{S_{JT}}{L_{JT}A_A} + \frac{A_{PR}}{A_A} + K_L\right]$$

P = pressure drop in psi over the length being considered.
l = total length in feet of the joint being considered.
t_Y = yield point of the mud in lb per 100 sq ft.
D = pipe ID in inches for internal flow or bit size minus pipe OD in inches for annular flow.
n = plastic viscosity of the mud in Centipoise.
A_A = area in sq ft of the annulus alongside the diameter being considered.
K_L = constant from clinging effect in laminar flow. .39 for drill pipe; .46 for casing

Formula 13—General Equation for Reynolds Number for Turbulent Flow in Annulus

$$R = \frac{396\,D\rho V_P}{n}\left[\frac{S_{JT}}{L_{JT}A_A} + \frac{A_{PR}}{A_A} + K_T\right]$$

R = approximate Reynolds number in turbulent flow.
ρ = mud weight in lb per cu ft. (7.48 × lb per gal.)
K_T = constant from clinging effect in turbulent flow .166 for drill pipe; .181 for casing

Formula 14—General Equation for Hydraulic Pressure Drop for Turbulent Annulus Flow

$$P = \frac{0.001296\,f\,l\rho V_P^2}{D}\left[\frac{S_{JT}}{L_{JT}A_A} + \frac{A_{PR}}{A_A} + K_T\right]^2$$

f = Pigott friction factor from Fig. 1.

Formula 15—General Equation for Acceleration Pressure in the Annulus

$$P = 0.0002155\rho l a_P\left[\frac{S_{JT}}{L_{JT}A_A} + \frac{A_{PR}}{A_A}\right]$$

Use of Formulas

In order to get a closer picture of the preceding formulas, it would be best to take an actual case of a well being drilled with an 8¾-in. bit on 4½-in. drill pipe with 6⅛-in. OD IF Tool Joints using 300 ft of 6½-in. OD Drill Collars. The well is to be cased with 7-in. OD casing for completion. Let us assume that the mud, which weighs 112 lb per cut ft (15 lb per gal.), has a yield point of 15 lb per 100 sq ft and a plastic viscosity of 35 centipoises.

Lowering of Drill Pipe

Fig. 4 shows a velocity and acceleration curve typical of a 90-ft stand of drill pipe or tubing being lowered in the hole, during which operation a total return of 10¼ cu ft (which would represent a drill pipe float or a plugged bit) was observed. Since the total pressure is calculated as the sum of the hydraulic losses and the acceleration or deceleration pressure, both of these basic components, as well as the total of the two, are shown in Fig. 5, which gives the pressure generated as a function of time. As the pipe is first set in motion, the hydraulic losses equal the yield strength of the mud and then slowly build up as laminar flow is formed. At 1.7 seconds, the drill collars break into turbulent flow and the friction loss takes an upswing. At 2.3 seconds, the tool joints also become

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The last 8,000 ft. to TD of 17,895 in this well at Coles Levee in Kern County, California was drilled and cored with Black Magic. The producing interval is 17,500 - 17,895 feet from the Eocene. It came in flowing to become the world's deepest commercial producing well. Casing (7") was run and cemented in Black Magic at 17,500—one of the deepest cementing operations that has ever been performed successfully.

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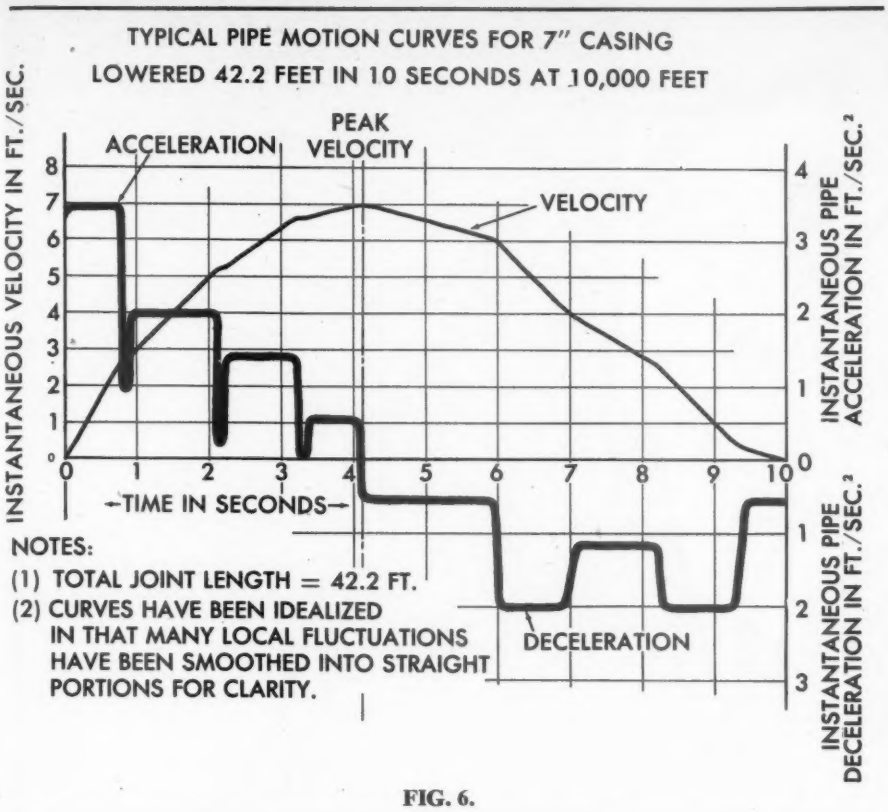
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INSTANTANEOUS VELOCITY IN FT./SEC.
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ACCELERATION
VELOCITY
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←TIME IN SECONDS→
DECELERATION
NOTES:
(1) TOTAL JOINT LENGTH = 42.2 FT.
(2) CURVES HAVE BEEN IDEALIZED IN THAT MANY LOCAL FLUCTUATIONS HAVE BEEN SMOOTHED INTO STRAIGHT PORTIONS FOR CLARITY.

FIG. 6.

turbulent, and at 4.6 seconds the entire annulus is in turbulent flow with losses building up very rapidly to a maximum coincident with the pipe velocity peak. This pressure falls off with decreasing velocity along the same pattern and returns to the yield value as the pipe stops. The acceleration pressure, on the other hand, follows the shape of the pipe acceleration curve, rapidly rising to a fairly high value. It then changes each time the driller changes the braking pressure, eventually going back to zero and on into deceleration values. The actual shape of this curve will depend essentially on how the driller handles the brake and whether or not the hydromatic brake is engaged. Every time the driller changes his braking pressure, there will be a rather sharp discontinuity in the acceleration value, particularly during the later portion of the cycle. It is interesting to note that, during deceleration of the fluid, the bottom-hole pressure is lessened below hydrostatic through having to bring the annular fluid to a halt.

The net bottom-hole pressure is then taken as the sum of these two pressures and is of the shape indicated by the heavy curve in Fig. 5. It rises almost immediately as the pipe starts in motion, and continues to rise to a peak somewhat prior to the point of maximum velocity. After this it falls off rapidly, going down below the normal fluid pressure during portions of the deceleration cycle. The height of the peak shoud be carefully noted, particularly in terms of the effective change in mud weight. There are many areas in which such a significant change in mud weight (either positive or negative) would create very definite problems.

If the pipe is set very roughly in the slips, the terminal deceleration values could be quite high and create a considerable, although very short-lived, negative pressure shock at the bottom of the hole. It should be noted that these values are considerably different from those that would be obtained by simply assuming the joint to be dropped at an average velocity equal to its length divided by the dropping time.

Lowering of Casing

In view of the decreased clearances, the pressure that will be encountered when this well is cased will be of a considerably higher nature, particularly if the casing is floated in. A typical velocity-and-acceleration curve for 7-in. casing in 8¾-in. hole as a function of the dropping time is shown in Fig. 6. From this, the two basic components and their sum can be calculated as shown in Fig. 7. Essentially these curves have the same shape as the drill pipe curves except that even the laminar flow portion has quite a steep slope due to the decreased hydraulic diameter of the annulus. The magnitude of the peak pressure for this illustration should definitely concern even those who operate in areas that have exceptionally good formation strengths. This pressure rise is, in almost all areas, sufficient to bring the total pressure of the well bore well above the geostatic gradient and tend to fracture even the best formations to relieve itself.

In order to illustrate the value of some of the recommended protective measures that can be used during a casing job to lower the bottom-hole pressure, Fig. 8 shows for this same casing condition the effect of increasing the dropping time. *It is very important to note that a 3-sec increase in dropping time will give a 37¼ per cent decrease in bottom-hole pressure, but a 10-sec increase in dropping time would give a 70½ per cent decrease.* Yet on a 10,000-ft well with 40-ft joints, a 3-sec increase in dropping time would amount to a total increase in the casing job only 12½ minutes, whereas an increase of 10 seconds in dropping time would increase the total job by only 42 minutes. This certainly seems like a remarkably low price to pay for the decrease in bottom-hole pressure that is gained.

A second remedial step that can be taken is the use of some sort of control device on the bottom of the casing that will allow the casing to fill during the dropping cycle and decrease the total volume displaced up the annulus. This effect is best illustrated in Fig. 9, which shows the separate values for 100 per cent, 90 per cent, and 81 per cent fill of the casing and (for purposes of comparison) the value for a 0 per cent fill that would apply when casing is run with a float shoe. This again can give excellent control over the dangerously high pressures developed during a conventional job and, contrary to the previous examination, actually saves about 15 to 20 minutes per 1000 feet because top fill is eliminated.

The value for 100 per cent fill during drop, although shown as an ideal case, is very difficult to design, since, with no safety factor, the slightest variation from the expected conditions would cause overflow. In using Fig. 9, the per cent fill that occurs while making up the next joint must be discounted, because it does nothing to relieve pressure surges.

Also, in setting up programs through potentially dangerous formations some consideration should be given to a third effect of the hole size or the bit size as it affects these bottom-hole pressure surges. The effect of changing the size of the drilled hole is shown in Fig. 10 where 7-in. casing is run in 8¾, 9⅞, and 10⅝ open hole. A relatively small increase in clearance has a remarkable effect on the bottom-hole pressure near the critical range.

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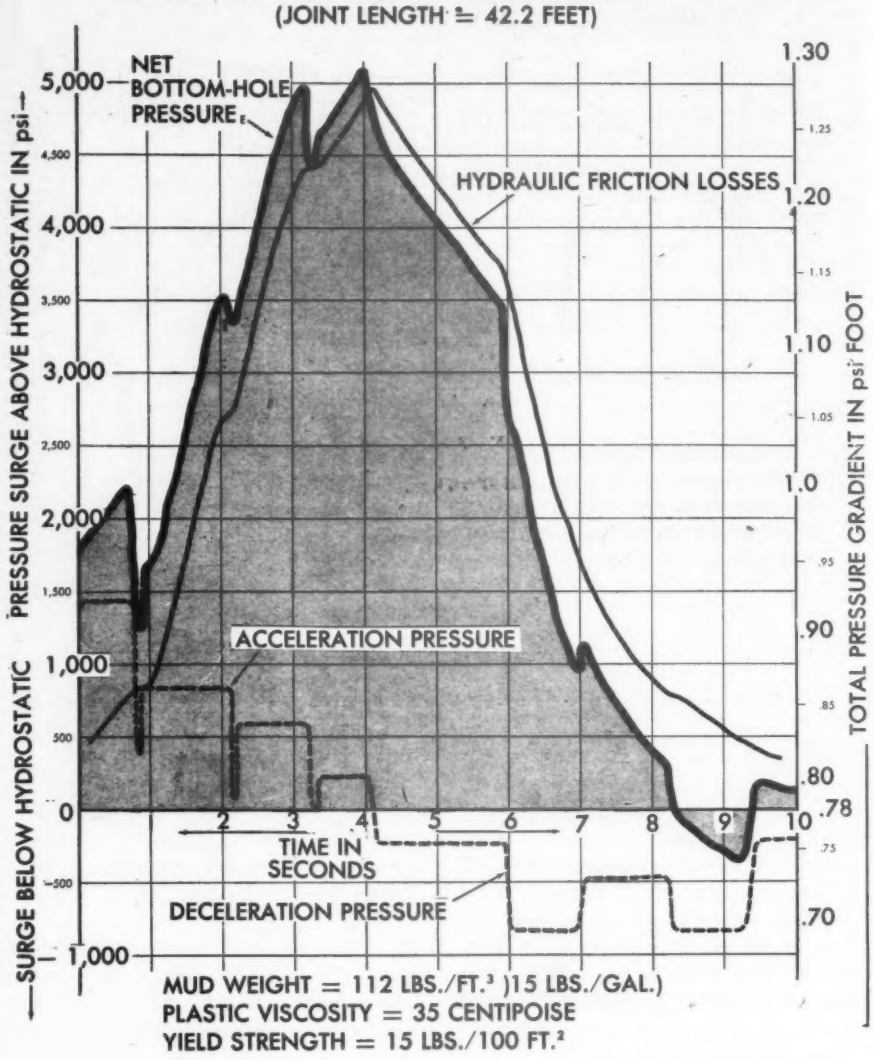

FIG. 7.

Spudding Drill Pipe While Circulating

Another point of danger, in which extremely high pressure can develop during the drilling operation occurs when the pipe is spudded while circulating. The normal practice of many drillers is to pull back up after they have made a certain amount of hole and, with the pump running wide open, ream back through the drilled area. As a general rule, this is also accompanied by an unnecessarily high rate of acceleration and deceleration. The net result, as shown in Fig. 11, is the application of a surging effect due to the pipe movement as well as to the steady circulating pressure already imposed on the bottom of the hole. Although these calculations are quite tedious and require a considerable number of trial-and-error solutions, the results are quite informative in that they show why pressures do not go up as high as might be expected.

Before the spudding is started, the pump pressure is expended principally in turbulent flow inside the drill pipe with the annulus still in laminar flow. As pipe motion starts, however, the entire displacement of the drill pipe must come up the annulus in addition to the circulation volume and this, along with the "carry-down" clinging to the pipe, causes a break into turbulence, with rapidly increasing annulus resistance. The net result is that the increasing bottom-hole pressure bucks the pump pressure and decreases the pumped volume, thus partially easing the pressure rise. On the other hand, acceleration pressures generally reach large proportions on this type of spudding, since pipe accelerations go up to eight or more ft per sec² during portions of the drop. In the example

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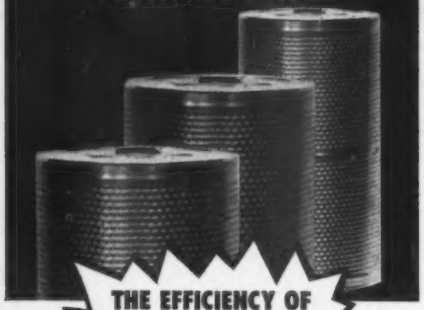

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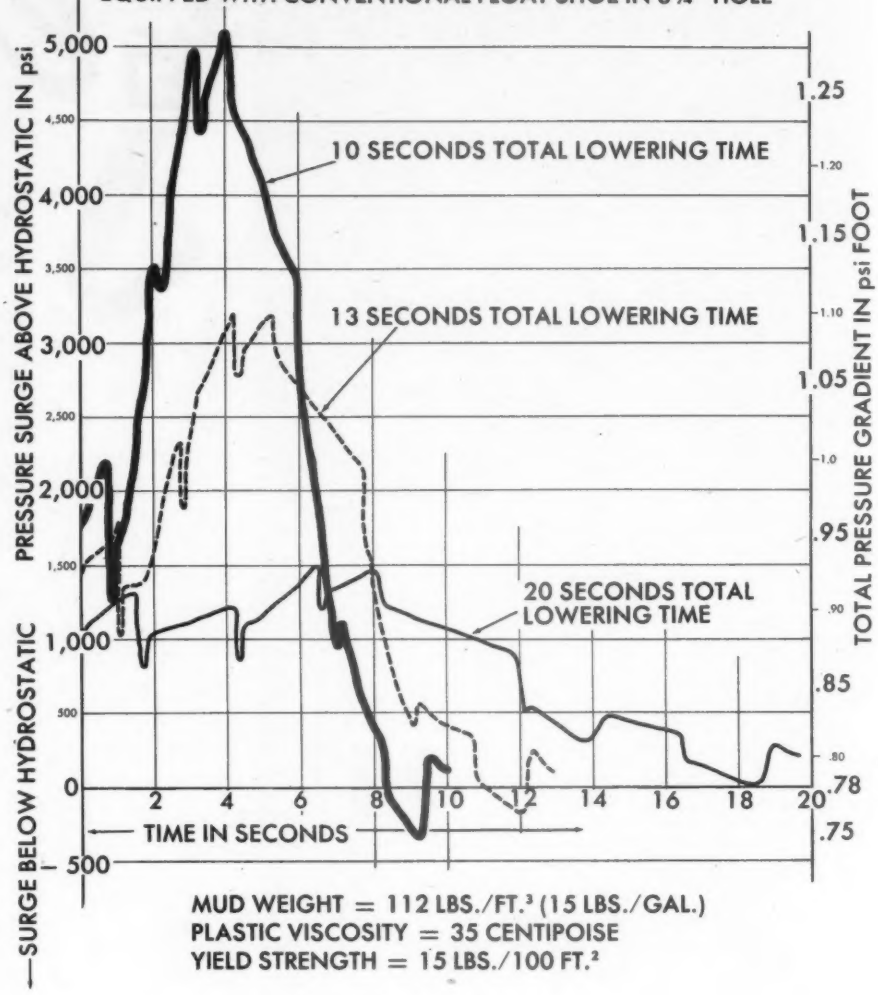
EFFECT OF INCREASED LOWERING TIME ON BOTTOM-HOLE PRESSURE

WHEN LOWERING 10,000 FT. OF 7" FLUSH-JOINT CASING EQUIPPED WITH CONVENTIONAL FLOAT SHOE IN 8¾" HOLE



MUD WEIGHT = 112 LBS./FT.³ (15 LBS./GAL.)
PLASTIC VISCOSITY = 35 CENTIPOISE
YIELD STRENGTH = 15 LBS./100 FT.²

FIG. 8.

plotted, acceleration amounted to almost 60 per cent of the peak pressure and accounted for the drop below hydrostatic when stopping. If rapid spudding were attempted with casing, the bottom-hole pressure could rise sufficiently high to stop the pump circulation entirely.

Pressure Distribution Up the Hole

To complete the picture, an analysis of the pressures existing up the bore from these bottom-hole pressures should be illustrated. Fig. 12 shows the distribution of pressure with depth at the instant of peak surge from Fig. 5. (Since the tool joint drops would be indistinguishable if each were plotted in place, they have all been grouped for clarity at the bottom of the string.) In addition to the hydraulic losses and and acceleration components, a third component—velocity energy—enters as the analysis moves into the area alongside the pipe.

Fortunately, this effect is negligible (only 2.3 psi at the most restricted section and carrying only .205 psi pressure energy into the mud pits in the form of motion). This energy carried out of the hole into the mud pits is additive to the bottom-hole pressure calculated by the preceding formulas, but velocities would have to reach blowout proportions (50 to 100 ft per sec.) before they would have any noticeable effect on calculations. It should be noted that the higher pressures previously calculated exist not only at the bottom of the hole, but also proportionately along the entire well bore. In this picture, the loss of head resulting from any turbulence and expenditure of energy into heat at a sharp discontinuity has been neglected. This type of

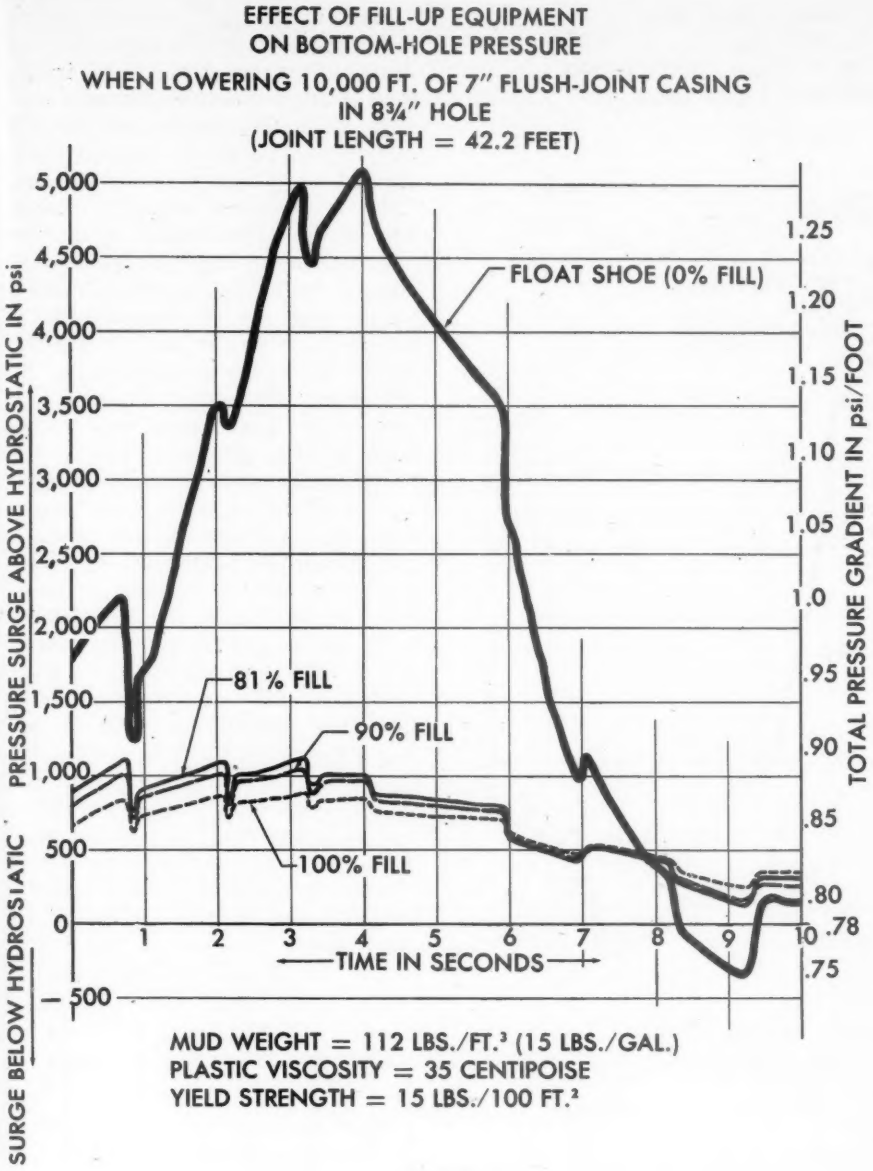


FIG. 9.

loss is additive to all other values and, to maintain the same state of fluid motion, will increase the bottom-hole pressure by the amount of the lost head. In effect, such an action amounts to that of an annular orifice and is one of the largest factors in the pressure surges caused by a balled bit. Generally the ball is so short in length that calculations of hydraulic losses alone do not give a true picture of the actual loss.

The importance of enlarged sections (even neglecting sudden turbulence losses) can be noted by the change of slope on each of the component factors of bottom-hole pressure. The higher velocities, local displacements, and decreased hydraulic clearances all compound into rapidly increasing pressures and serve to point out the value of adequate clearance.

Complicating Factors

In actual practice, however, the creation of pressure above the geostatic gradient or above existing formation strengths, as calculated from these formulas, is not possible. After passing a certain point, the formation will no longer contain the pressures being created. When this condition is reached, the fluid will relieve the pressure by going into the walls of the hole rather than up the annulus. It should be pointed out that this particular action can occur even though approximately 100 per cent of the mud is eventually returned to the surface.

The mechanics of such action are that, in addition to compression of the mud, the earth will lift, fracture, or simply expand elastically, allowing a storage of fluid during the high-pressure portion of the cycle. Then, as the pressure is relieved by the slowing of the pipe, the settling back or the elasticity of the formation will force this stored fluid back into the annulus and thence on up the well bore.

This effect can often be seen while running drill pipe, or even while running casing equipped with floating equipment, by looking down the annulus from the cellar or by closing the shaker drain so that annular fluid motion can be seen. During the first portion of the dropping cycle the annulus will actually fall, and it is not until the pipe is beginning to decelerate that the formation will stop storing up the fluid and mud will begin to come up the annulus.

The fluid will then continue to be squeezed out and displaced by the settling formation or expanding mud for some time after the casing has actually come to a complete stop. In some areas this effect of nature, relieving a pressure that it cannot support, can go so far as to cause the entire pipe displacement to occur after the joint has come to a complete stop, even though the actual displacement will show only a very small net loss to the formation.

Another complicating factor that should be pointed out as yielding differences between calculated values and actual values is the effect of long periods of quiescence, temperature, and pressure on the down-hole mud relative to the surface mud on which viscosimeter readings are taken. This is particularly true of laminar flow, where pressures are highly dependent on the yield strength. In such areas as the Gulf Coast, this factor can greatly increase actual values over the calculated values. External projections on either drill pipe or casing (such as scratchers, centralizers, baskets, drill pipe protectors, or balled bits) are very difficult to analyze because of their irregular shape and, in some cases, their sudden energy loss due to local turbulence.

Bridging of any portion of the annular section, or hole growth, presents similar complications and is generally too unpredictable to account analytically, although in some areas this may be possible.

The compressibility of the confining walls, compressibility of the mud, lack of the assumed concentricity between pipe and hole, as well as the loss of fluid, further deviate from the mathematical picture. Despite all these complicating factors, however, the ability to predict the bottom-hole pressure to a first order of magnitude is not seriously impaired, because many of these factors will compensate each other. If nothing else, these formulas at least serve to make one cognizant of the factors that enter into pressure surges and how they may be conquered.

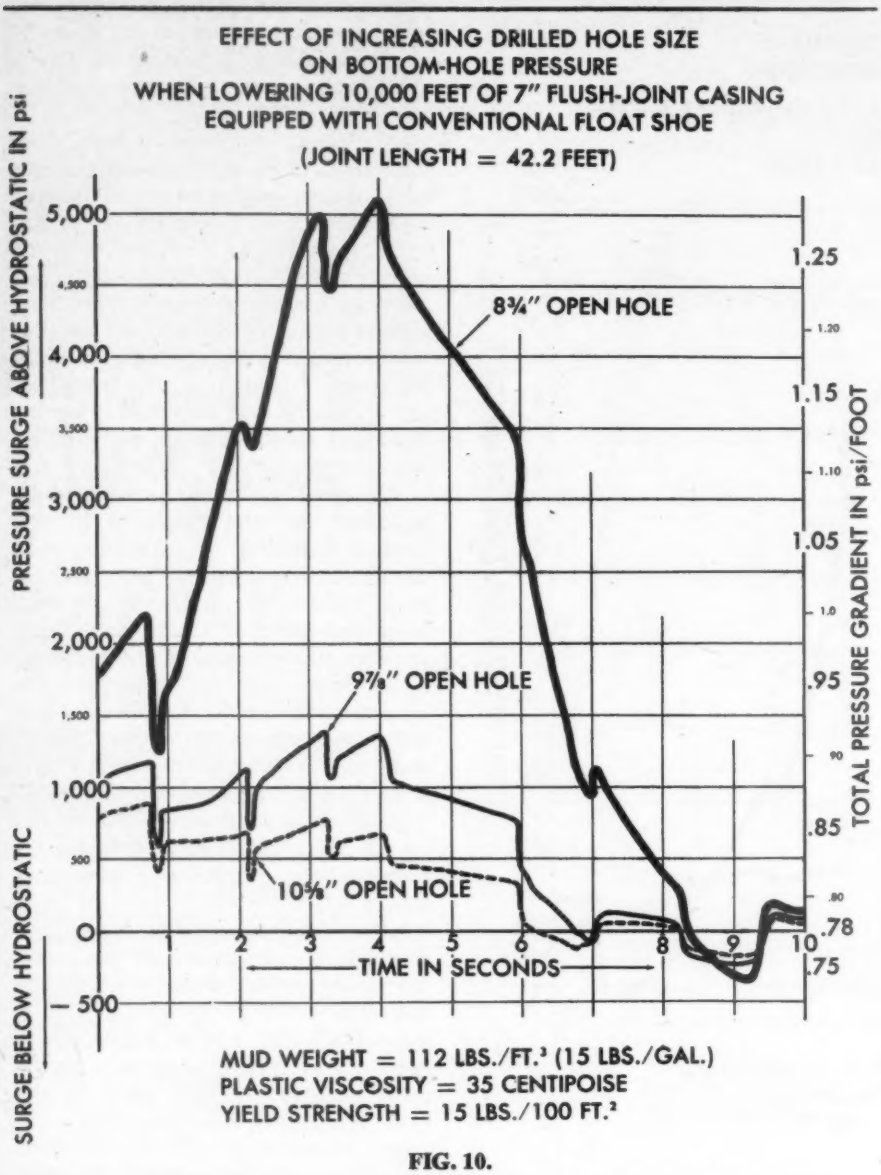

EFFECT OF INCREASING DRILLED HOLE SIZE
ON BOTTOM-HOLE PRESSURE
WHEN LOWERING 10,000 FEET OF 7" FLUSH-JOINT CASING
EQUIPPED WITH CONVENTIONAL FLOAT SHOE
(JOINT LENGTH = 42.2 FEET)
PRESSURE SURGE ABOVE HYDROSTATIC IN psi
SURGE BELOW HYDROSTATIC
TOTAL PRESSURE GRADIENT IN psi/FOOT
8¾" OPEN HOLE
9⅞" OPEN HOLE
10⅝" OPEN HOLE
TIME IN SECONDS
MUD WEIGHT = 112 LBS./FT.³ (15 LBS./GAL.)
PLASTIC VISCOSITY = 35 CENTIPOISE
YIELD STRENGTH = 15 LBS./100 FT.²

FIG. 10.

Conclusions

The bottom-hole pressures that are created either positively or negatively by the running or pulling of drill pipe, casing, or tubing, have proved themselves to be a very great source of potential trouble. As calculated in several illustrations, it is easy to see that the actual surges can do much damage even though the immediate effect of lost circulation, blowouts, or stuck drill pipe is not in evidence.

As has been pointed out by the calculated values of pressure changes, surges can rise above the geostatic gradient during downward motion or fall considerably below the hydrostatic during withdrawal. Fractures created by high positive surges not only can cause immediate losses of mud, but also can create a continuous trouble spot through a permanent lowering of formation strength.

If such fracturing occurs in a vertical plane during the extremely high surging encountered on a casing job, it can bypass several thousand dollars worth of primary cementing and make one to ten squeezes necessary in order to control. This is particularly true where protective strings are set only a short distance through critical spots or where oil strings are set through closely spaced zones.

On the other hand, high pulling reductions can undo all the corrective measures taken to seal off natural permeability or man-made fractures by letting formation pressure slough off protective wall cake. If sufficient increase occurs in the percentage of cuttings from this wall cake or even "sucked-in" formation carried in the annulus mud, drill pipe can become stuck either in a key seat or in a bridged-off section. A compounding of damage from reduction surges can occur through a mistaken analysis, especially if the formation pressures contain gas.

The decrease in fluid weight from "sucked-in" trip gas is often misinterpreted into abnormal bottom-hole pressures and increased weight of drilling fluid is often recommended as a solution. Since the average weighting is accompanied by increased yield strength and plastic viscosity, it is possible for the suction surges to increase beyond the added weight so that the gas continues or even gets worse. Conversely, both the increased positive surges and the unnecessary added weight put a terrific load on the formation during the dropping cycle.

Consequently, it is recommended that pressure-reduction methods be adopted as a general practice, even though little *apparent* trouble is being encounted during drilling or completion. Although most of these practices will require a certain amount of enforcement because of their deviation from present standards, they will actually cost an operating company practically nothing. When added up along with all of the lost time encountered from "unavoidable" delays, or the time actually spent in the hole drilling, the few extra dollars spent in precautionary measures will be virtually impossible to find in the over-all cost of the well. Yet, the savings in actual cost, both of original completion and of further workover, can be considerable.

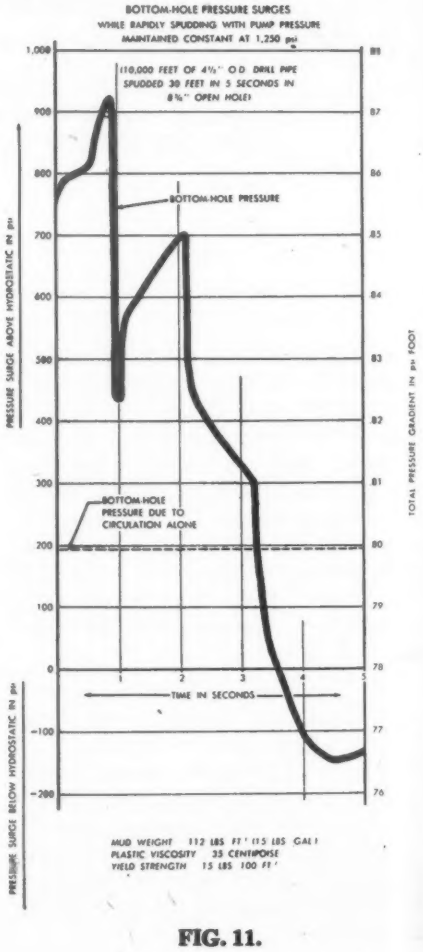

BOTTOM-HOLE PRESSURE SURGES
WHILE RAPIDLY SPUDDING WITH PUMP PRESSURE
MAINTAINED CONSTANT AT 1,250 psi
(10,000 FEET OF 4½" O.D. DRILL PIPE
SPUDDED 30 FEET IN 5 SECONDS IN
8¾" OPEN HOLE)
BOTTOM-HOLE PRESSURE
BOTTOM-HOLE
PRESSURE DUE TO
CIRCULATION ALONE
TIME IN SECONDS
PRESSURE SURGE ABOVE HYDROSTATIC IN psi
PRESSURE SURGE BELOW HYDROSTATIC IN psi
TOTAL PRESSURE GRADIENT IN psi/FOOT
MUD WEIGHT 112 LBS./FT.³ (15 LBS./GAL.)
PLASTIC VISCOSITY 35 CENTIPOISE
YIELD STRENGTH 15 LBS./100 FT.²

FIG. 11.

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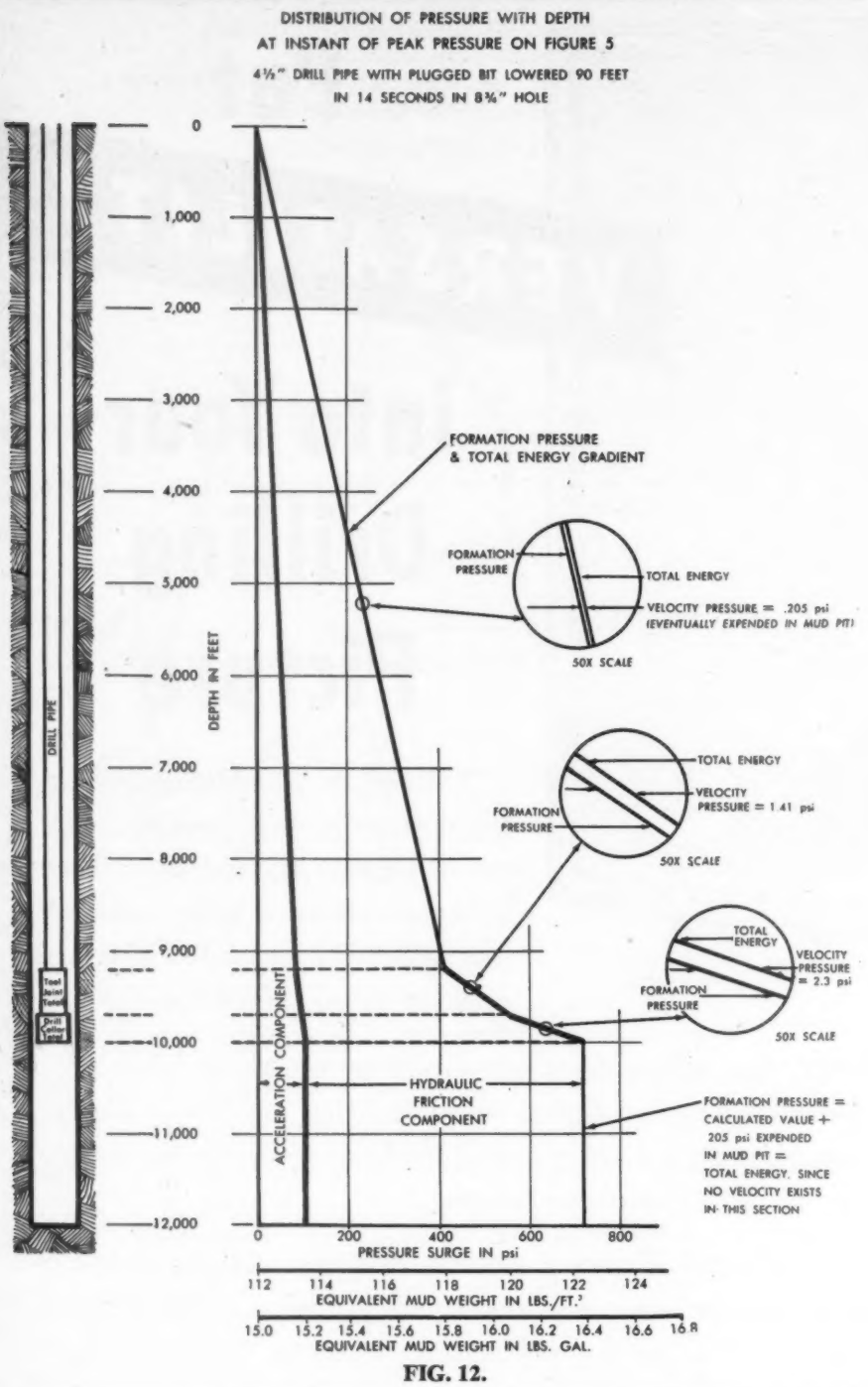

FIG. 12.

It is recommended that the following pressure-reduction practices be instituted as standard procedures, even where lost-circulation difficulties are not expected:

1. **Increase running or pulling times sufficiently to keep pressures safely above zonal hydrostatic pressure, but below the formation strength at all times.**
2. **Decrease the rate of acceleration or deceleration of the pipe through smoother brake handling and earlier use of the hydromatic brake.**
3. **Use bottom fill devices (wherever they are feasible commensurate with other problems that might exist) to relieve annulus volumes by internal filling.**
4. **Increase clearances wherever possible. (Although this concept is affected by so many other economic factors that the recommendation of changing programs would be inadvisable on this basis alone, there is a point of decreased clearance at which the bottom-hole pressures will begin a very rapid upward swing. This should definitely carry some weight along with the other economic factors determining a given drill pipe, casing, and open-hole relationship.)**
5. **Care should also be used with projections above pipe size such as oversize drill collars, and drill pipe protectors, or improperly designed centering and scratching equipment run on casing. These projections can compound pressure build-ups, particularly if they should create excessive pressure losses because of local turbulence and eddies.**
6. **The practice of spudding back through previously drilled formations, using high rates of pumping as well as high rates of pipe acceleration and deceleration, should be definitely controlled.**

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5. "Mud Flow in Drilling," R. S. J. Pigott, *API Drilling and Production Practice*, 1941 Edition, Page 91.
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* * *

GAS IN ARCTIC CIRCLE

Although the United States probably is the greatest producer of natural gas in the world, geologists continue to discover this fuel in remote corners of the earth. An extensive deposit of oil was found in Umiat, in the Naval Petroleum Reserve in the Arctic Circle. One large natural gas field also was found there. However, because of the expense involved in transporting oil and natural gas from Northern Alaska, the Navy believes that at least four fields that could produce at least 100,000 barrels daily would be needed to make the venture profitable.

BLOWOUT PREVENTERS

MARVIN R. JONES*

EXPERIENCE has proved that mechanical equipment must be used to supplement the hydraulic system used to control formation pressures encountered in rotary drilling operations.

A possible assembly of equipment designed to effect such control is shown in Fig. 1. Starting from the bottom, the elements shown are:

1. A combination unit including a blowout preventer and a master valve.
2. A drilling spool.
3. A blowout preventer.
4. A blowout preventer.

From the drilling spool, to the right, is shown a flow line valve and a flow line. To the left are wing valves and a choke. Not shown in the figure but necessary for the operation of the equipment shown are a source of operating pressure and a control manifold for directing that pressure.

There is no standard assembly, and the possible variations are almost infinite. Special arrangements, and special equipment are used to meet various special conditions, but operators differ widely on what is the best hook-up.

Function of Elements

A blowout preventer is a valve designed to close off the annular passage formed between a large pipe to which it is attached, and a smaller pipe contained inside the large one. They are required to seal around pipe which may be moved, which may have a rough outer surface and which may be submerged in a highly abrasive fluid.

A master valve is simply one designed to close a passage formed by the extension of a well casing or tubing. In present day practice, most master valves used for drilling are simply standard blowout preventers equipped with closing members adapted to close an open hole.

Drilling spools are fittings used to provide operating space between elements on the one hand, and access to the well bore on the other. Many assemblies do not use spools, using arrangements providing operating space, and units having side outlets for access.

Flow line valves are similar in function to master valves, being employed to close lateral passages that are usually smaller than the well bore, under conditions much the same as those with which the master valve operates. Here again, many assemblies are so arranged that no flow line valve is required, with the return flow of mud coming away from the well bore above the top preventer.

A wing valve is similar again to the two previously mentioned valves; it is used to close the passage between the well bore and the choke.

The function of the choke is to throttle the return flow of mud when that flow is caused by well pressures over which operator has no control.

Besides the equipment shown, numerous other units are commonly used from time to time to control pressures in the well bore. Some of these seals are what could be called "working pack-offs" as compared to the emergency pack-offs; and they are used to control pressures developed intentionally at the surface of the well. Such cases occur when it is necessary for some reason to use a circulating fluid whose weight only partially offsets the formation pressure. They also occur when it is necessary to apply pressure to the well bore during operations to achieve some particular result.

Other equipment not shown includes such elements as drill stem float valves, kelly cocks, and internal blowout preventers of various types.

Summed up, control assemblies of this sort are used primarily to control formation pressures in a well bore during drilling operations when it is either not possible or not practical to control them entirely by hydraulic means, that is by weighting drilling fluid.

Pressure Control Assembly

For the purpose of a more specific examination of the various elements assembled to control the pressures we have discussed, it is possible to consider two general groups: primary equipment and secondary equipment.

Elements classified as primary equipment can be described as those designed and used for the purpose of holding safely whatever pressure the formation may be able to impose on the assembly it is a part of.

As stated previously, master valves are those units used to close the open well bore and hold whatever pressures may be developed. In the past, conventional steel gate valves were used for this purpose, but at the present time, the large majority of master valves are blowout preventers with rams adapted to make a closure on the open hole. This has come about because of the necessity of making a leak tight closure under extremely adverse conditions and because of the necessity of making operating time as short

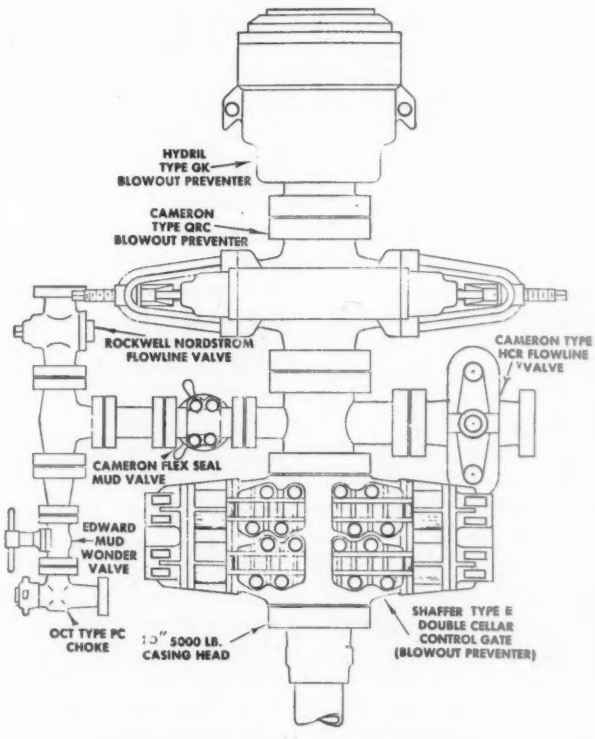

HYDRIL TYPE GK BLOWOUT PREVENTER
CAMERON TYPE QRC BLOWOUT PREVENTER
ROCKWELL NORDSTROM FLOWLINE VALVE
CAMERON TYPE HCR FLOWLINE VALVE
CAMERON FLEX SEAL MUD VALVE
EDWARD MUD WONDER VALVE
OCT TYPE PC CHOKE
5000 LB. CASING HEAD
SHAFFER TYPE B DOUBLE CELLAR CONTROL GATE (BLOWOUT PREVENTER)

FIG. 1. Possible assembly of equipment.

*Petroleum Mechanical Development Company, Houston, Texas.

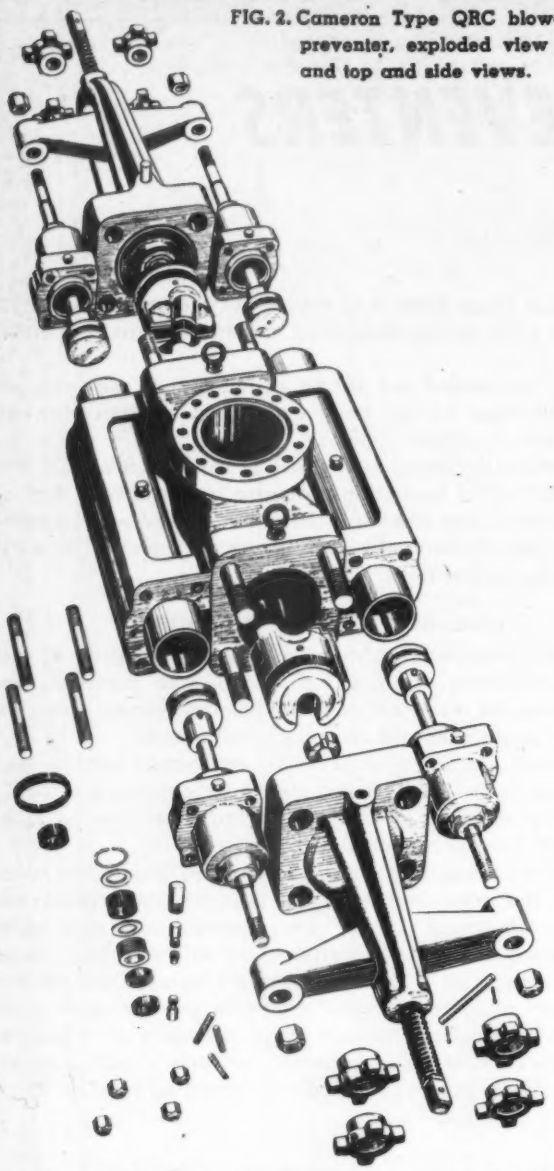
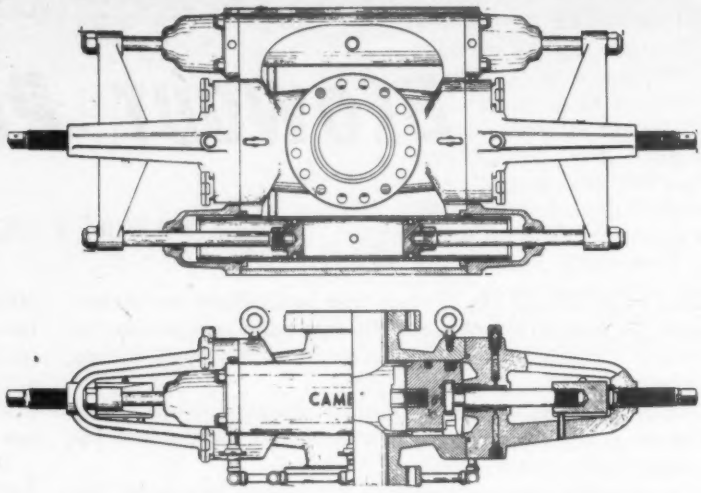


FIG. 2. Cameron Type QRC blowout preventer, exploded view and top and side views.



as possible. Such practice also employs more flexible equipment. For some years two or three special types of master valve were used, and some few of these valves are still in use. The practice is not common, however, and the discussion on blowout preventers will cover the equipment most usually used for master valves.

Blowout Preventers

API Standard 6E states our definition of a blowout preventer in these words: "A blowout preventer is a unit attached to the casing or to a unit of wellhead equipment installed thereon for the purpose of controlling pressures in the annular space between the casing and an inner string of pipe during drilling and completion operations." This definition is not quite broad enough to cover all blowout preventers in the sense that the term is sometimes used to describe units used with wire rope, lines, or sucker rods; or may be applied to devices used inside drill pipe. The following remarks are limited to the meaning of the definition.

Ram Type Preventers

Ram type preventers of one sort or another form the basic element in almost all pressure control assemblies today. In this sense, a ram is defined by the standard just quoted as "a unit retractable from the bore of a wellhead or blowout preventer, which in its extended position engages a pipe to effect a seal in the annular space between the well head or blowout preventer, and may provide a means of support for the pipe." These rams described are customarily retracted by sliding or by rotating them out of engagement.

Two types of ram construction are popular: cylindrical and flat. Only one unit using cylindrical rams adapted to slide in and out of round bores opposing each other at right angles to the axis of the wellbore is currently extensively manufactured and used.

Cameron Type "QRC" Blowout Preventer

Fig. 2 illustrates Cameron Type QRC, which has these features considered to be advantages and disadvantages:

Advantages

1. It has high pressure capacity.
2. It operates reliably with minimum maintenance.
3. Maintenance is reasonable in cost.
4. Its overall height is low compared to most annular preventers.
5. It is simple.
6. Ram change is easy.
7. Rams are interchangeable between pressure ratings.
8. Rams have high pipe hanging capacity.
9. Ram front packings have high wear volume.
10. Operating speed is fast.
11. Well pressure tightens ram seal.

Disadvantages

1. Overall height is more than that of flat ram preventers.
2. Corresponding rams and packing are required for each pipe size.
3. Preventer can be installed upside down.
4. Too much cellar space is required for ram change.
5. It is difficult to test between rams as test pressures tend to make lower rams leak by forcing them open.
6. Two preventers are required to work pipe in or out of the hole under pressure.
7. QRC is heavy as compared with flat ram units.
8. Piston and operating rods are exposed to dirt and damage.
9. It cannot be opened manually.
10. Close fitting rams require more maintenance to prevent sticking than do looser fitting ones.

Care and Maintenance. Maintenance of QRC preventers is simple. In use, any ram type preventer should be operated at least once each day and better yet, once each tour. If more than 150 psi operating pressure is required, the preventer should be disassembled in conformance with the manufacturer's manual and the reason for hard operation ascertained at the first opportunity. Some of the reasons for hard operation are damage to the rods, dirt or other foreign material, and misalignment. Rust on the ram bore or on the

ram, and swollen packing can also interfere with normal operation.

During each disassembly, all working parts should be cleaned and lubricated with the proper lubricant.

It is a highly profitable practice to disassemble, clean, lubricate, and reassemble each preventer at regular periods, perhaps at moving time, and always before storage periods. Particular attention should be paid to the flanges at the time of any disassembly of units. Probably more serious leaks have developed between flanged joints than at all other critical points combined. Ring grooves should be cleaned with a solvent, should be greased, and should be fitted with a wooden protector when not in use. Grooves in use should be protected with a light film of oil or light grease. Damaged grooves should be sent in to the manufacturer for repair.

The manufacturer's care and maintenance manual should be used for reference to all details of maintenance, and should be available to well crews at all times when the preventer is in use.

Flat Ram Preventers

Several makes of preventers employing flat rams are now popular. Most preventers of this type use designs in which the rams slide in and out of opposing ram bores in much the same fashion as the rams of the QRC do. One unit in this group, however, rotates the rams into engagement about a horizontal axis at the upper rear of the ram.

Shaffer Type "B" Blowout Preventer

FIG. 3 shows various views of the Shaffer Type "B" preventer, called by the manufacturer a "hydraulic cellar control gate." This unit is one of the latest in a long line of flat ram preventers which have been extensively used. The "double gate" model, ordinarily using one set of "blind rams" adapted to close on open hole, and one set of "pipe rams" adapted to engage some particular size of pipe is most popular and is discussed here.

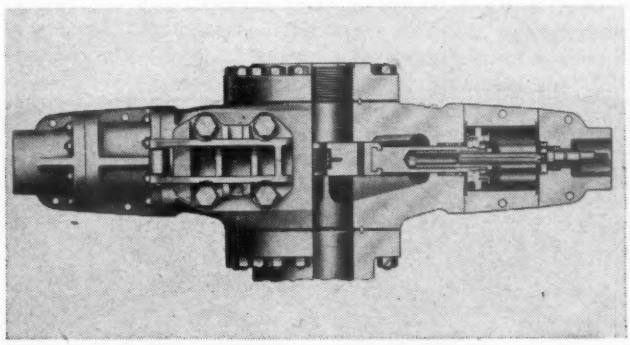
Although it is obvious that many of the advantages and disadvantages (or limitations) are identical to those of the QRC, users have mentioned some of the following as important features in their estimation:

Advantages

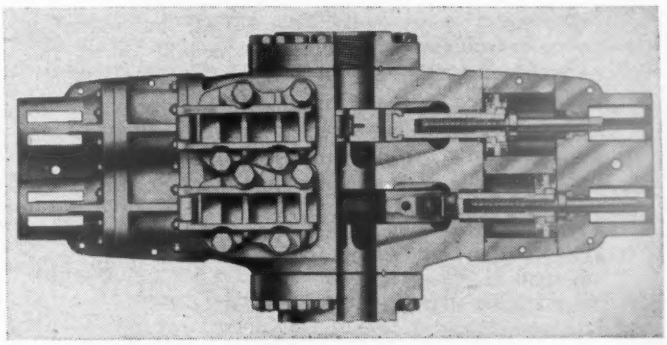
1. Its overall height is less than is possible or practical with cylindrical ram preventers.
2. Ram change is extremely easy and requires very little space.
3. Rams can be handled by hand.
4. Operating screw and rods are not exposed.
5. It is compact and light, as compared with round ram preventers.
6. Integral skids make for easy handling.
7. Fairly easy opening under pressure is often convenient.
8. Double construction eliminates one flanged connection.
9. Loose fit between rams and body in retracted position reduces danger of rams sticking.
10. Maintenance is very simple and inexpensive.
11. Rams have high pipe hanging capacity.
12. Ram chambers drain well.
13. Has high pressure capacity.
14. Lower rams can be changed without removal of upper rams.

Disadvantages

1. Unit cannot be opened manually.
2. Double design does not lend itself to maximum flexibility in the location of flowlines, choke manifolds, fill up lines or the like. (Single models do.)
3. Studded flanges are more difficult to handle without damage (to studs) on large units of equipment.
4. Corresponding rams and packing are required for each pipe size.



Shaffer Type B hydraulic single cellar control gate.
Non-rising stem.



Shaffer Type E hydraulic double cellar control gate.
Rising stem.

Loosen screw cap.

Open doors.

Slide out old ram.

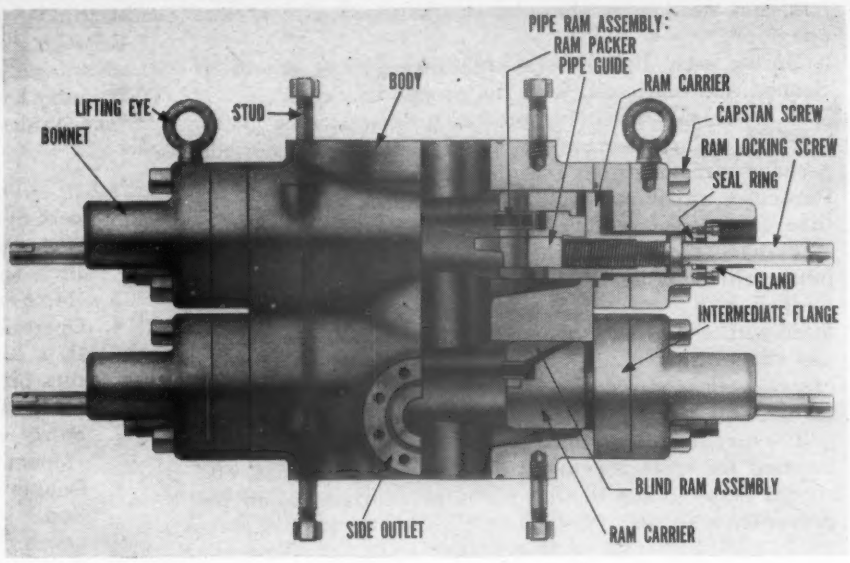
Slide in new ram.

FIG. 3. SHAFFER CONTROL GATES.

5. Two preventers are required for working pipe into or out of the hole under pressure.

Care and Maintenance. This unit should be operated once every day during drilling operations. If any increase in operating pressure is noticed, the rams should be removed at the first opportunity and should be cleaned and inspected. Ram recesses should be thoroughly washed and checked for dirt or nicks. If after correcting any conditions found, and if after operating several times, the preventer still requires too much pressure to operate, a company service man should be asked to check the unit.

In addition to the care and precautions mentioned in connection with the QRC flanges, studs should be protected from mechanical and corrosive types of damage while in transit or storage.



Cameron Type SS.

Shaffer Type "E" Blowout Preventer

Fig. 3 also shows a sectional view of the Shaffer Type "E" double gate preventer. Like the Type "B," it is available in either the double or single gate style, at the buyer's option.

The primary difference between the Type "E" and Type "B" preventers lies in the locking screw design. On the Type "E" preventers the screw moves in and out with the rams, whereas the others have non-rising stems.

No portion of either locking screw is exposed to well fluid or external mechanical damage.

General operating features, advantages and disadvantages, and maintenance required are the same as for the Type "B."

Cameron Type "SS" Preventer

This preventer is relatively new, having first made an appearance in Gulf Coast and West Texas fields during the early summer of 1953. Very little user comment is available, but examined in the light of comment provided on the two previous units discussed, it seems likely that the features listed will be considered desirable:

1. Its overall height is low as compared to round ram preventers.
2. It is compact and light as compared to round ram preventers.
3. Ram change is easy.
4. Operating rods and screws are not exposed to exterior damage. (They are exposed to well fluids.)
5. Double construction eliminates one flanged connection.
6. Large volume of ram front packing gives long wear.
7. No fluid lines are exposed.
8. Maintenance is simple and inexpensive.
9. Well pressure tightens ram seal.
10. Rams have high pipe hanging capacity.

It is reasonable to believe that the limitations and disadvantages of a basic nature will be for all practical purposes similar to those listed for Shaffer Type "B."

Care and Maintenance. Operate the "SS" preventer at least once a day while it is in use. Once a tour is better. Remove, clean, and inspect the rams if operating pressures go above 300 psi, or if they suddenly increase.

When rams and bores in good condition do not provide easy operation, use the manufacturer's manual as a guide to disassemble the cylinders for inspection and repair. Lubricate the unit as directed.

Release four capstan screws on each bonnet.

Operating pressure opens bonnets and withdraws ram assemblies.

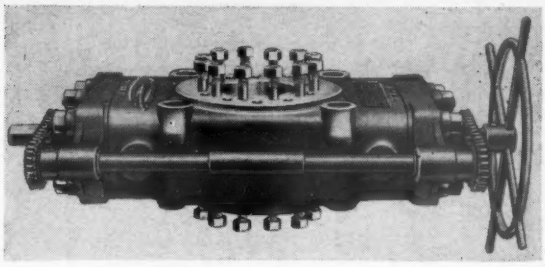
Ram may then be easily lifted from the preventer.

Pipe centering guide is also easily lifted out of preventer.

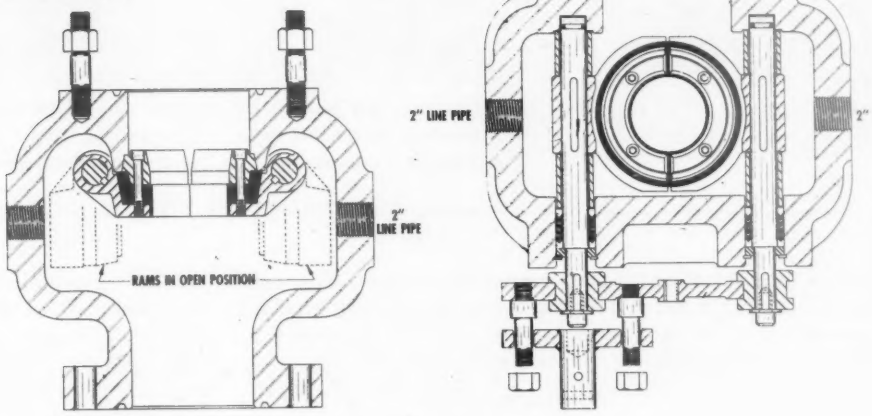
FIG. 4. CAMERON BLOWOUT PREVENTER

Guiberson Type "A" Blowout Preventer

Fig. 5 illustrates another fairly recent development. This unit is now used mostly for completions, recompletions, workover, and shallow drilling operations. No sizes larger than eight inch nominal have been seen, nor are large sizes listed in the manufacturer's catalogs. A unique arrangement is provided for connecting two of these units together to form a double unit comparable in overall height to other flat ram double units. One other feature is the provision of extra stud holes so that users may bolt the standard



Guiberson Type A



Omsco blowout preventer using rotating rams — photo and two cross sections.

FIG. 5.

body, made in only the 3000 psi cwp rating, to either the API series 600 or series 900 flanges without the use of adapters.

Although this unit has met with success in its introduction, no considerable amount of generally conceded opinion is found. Here again it is reasonable to believe that the general comment made on older equipment of the same general type will apply to some degree to this unit.

Care and Maintenance. Maintenance on this unit appears to be very reasonable and simple. Daily operation to insure maintenance of satisfactory condition, and cleaning and lubricating at regular intervals seem to be required in about the same degree as other ram type preventers. Yearly disassembly, cleaning, part inspection, repair, and replacement represents a wise investment on any unit of primary pressure control equipment.

Omsco Blowout Preventer

Fig. 5 also shows the Omsco blowout preventer, which is a highly popular unit using rotating rams. One model sometimes seen, but not shown, provides a third ram located ninety degrees away from the two pipe rams. This ram is blind and is used by itself to close the bore of the body when no pipe is in the hole. It allows the design of a preventer which combines the advantages of an overall height between that of round ram preventers and that of flat ram preventers, together with through bolted flanges.

Although these units are not new, it is impossible to develop enough comment to list the opinions expressed as consensus at this time. One remark worth consideration, however, was that ram packing pressure is developed entirely by well bore pressure. This precludes developing excessive packing pressures which would result in excessive wear against moving pipe. On the other hand, it is possible to conceive of occasions when higher packing pressure than that developed by wellbore pressure would be desirable. One other comment was that rams held pressure in only one direction, and that it was necessary to equalize pressures to open the preventer.

Care and Maintenance. Little is required in the way of maintenance on the Omsco preventer. Regular operation, cleaning and inspection will normally insure satisfactory operation.

Miscellaneous Ram Type Preventers

A small number of ram type preventers are being used other than those just described. Many of these are becoming obsolete and are used in non-critical installations while some are no longer manufactured. In all cases, however, these units are similar in general respects to one or more of the units described. No pressure operated ram type units in this group are known.

Advantages of Ram Type Preventers. Compared to other types of blowout preventers, ram types are generally conceded to afford compact size, low first cost, low maintenance costs, high pressure capacities, reliable operation and desirable operating characteristics.

Limitations of Ram Type Preventers. The primary limitation of the ram type preventers currently available is that ram and ram front packings must correspond in size to the pipe they engage.

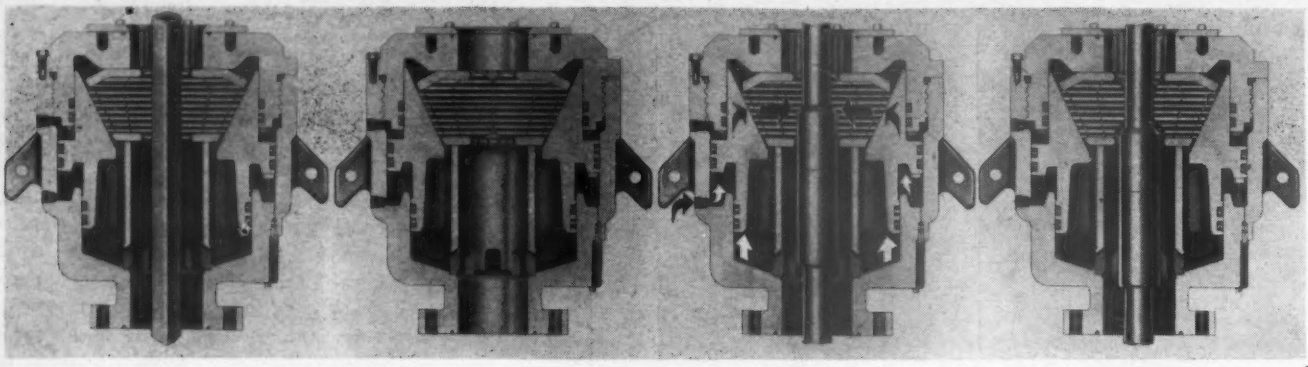
Annular Type Blowout Preventers

A purely arbitrary name for the type of blowout preventer, which uses a ring of packing material supported in some fashion by metal to close the annulus between the well pipe and the bore of the head is "Annular Type." Several types of units fall into this general classification.

Contractible Annular Type. The most popular type of annular preventer construction uses a ring of packing material with suitable reinforcement. This ring has the same inner diameter as the body of the preventer and remains in place ready for use at all times. Means are provided to constrict this ring until its inner diameter is small enough to engage and seal on a pipe, or even to effect a total closure on an open hole.

Hydril Type "GK" Blowout Preventer

Fig. 6 shows a cut-away view of the Hydril type "GK" blowout preventer. To operate this unit, liquid under pres-



Shows tight pack-off on kelly for holding high well pressures.

Pack-off on open hole safely holds well pressures equal to rated working pressure of preventer.

Shows tight pack-off for holding high well pressure and for preventing upward movement of pipe.

Shows controlled pack-off for easy stripping of tool joints.

FIG. 6. HYDRIL TYPE GK.

sure is introduced under the piston whose upper, inner surface is conical. Steel reinforcement in the packing element prevents upper movement of the element so that the conical surface of the piston forces the element to constrict.

Advantages

1. It seals on whatever size or shape is in the hole.
2. It seals on open hole.
3. One preventer can be used to work pipe into or out of the hole under pressure.
4. It reduces the number of preventers required.
5. It reduces the danger of pulling tool joints into the sealing element.
6. It is simple.
7. Packing elements have high wear volume.
8. Well pressure tightens seal.
9. Wear surface is under high circumferential compression.

Disadvantages

1. It costs more than some ram type preventers.
2. It is taller than ram type preventers.
3. It cannot be operated by hand.
4. It must be repacked from the top.
5. Time required for repacking is greater than for ram type preventers.

Care and Maintenance. Operation of the preventer periodically (two or three times a week is ordinarily adequate) insures that the unit will be in good operating condition when needed. It is not desirable in these operations to effect a closure on the open hole very often since the practice might produce some set in the packing which would keep it from opening to its full original bore.

When any positive increase is noticed in the pressure required to operate this unit, or when more than about 1300 psi is required to effect a complete closure on the open hole, the unit should be disassembled, cleaned, inspected, and defective parts should be repaired or replaced. Particular care should be taken to see that as little dirt and sand as possible is allowed to find its way into the operating cylinder, and the cylinder should be cleaned well at each disassembly.

Regan Types "K" and Torus Blowout Preventers

The Regan types "K" and Torus blowout preventers, as shown in Fig. 7, differ from the Hydril preventers in that the packing element is forced into sealing contact with the inner pipe by the direct action of a hydraulic fluid. Such a design is extremely simple and should be free of any tendency to stick. It has the ability to seal on all sizes and shapes of objects and can be used to work pipe with controlled operating pressure. No actual experience of any extent is available on the Gulf Coast, but it seems possible that the packing might have some tendency toward cold flow under higher pressures over extended periods of time. Far northern users of annular equipment have suggested use of flow lines above annular packings since low temperatures make for difficult operation and the mud returns provide some heat.

At the time of writing, the Torus preventer is a fairly recent development whose compact design seems to represent its most substantial improvement over its predecessors, together with the fact that it seems to have higher pressure capacity.

Care and Maintenance. Almost no maintenance is required to keep these units in safe condition. They should be operated and inspected periodically, and only pack-offs in reasonably good condition should be used. Normal protection of parts, particularly flanges, is about all the other maintenance required.

"Hosmer" Type Annular Blowout Preventers

One of the earliest approaches to the problem of closing the annular space between a well pipe and a casing was that of providing a split ring of packing and reinforcement which could be latched around the pipe and lowered to and secured in a special head. A considerable number of such units are presently being used, but only one type is being manufactured in any quantity.

OCT Type "J-1" Blowout Preventer

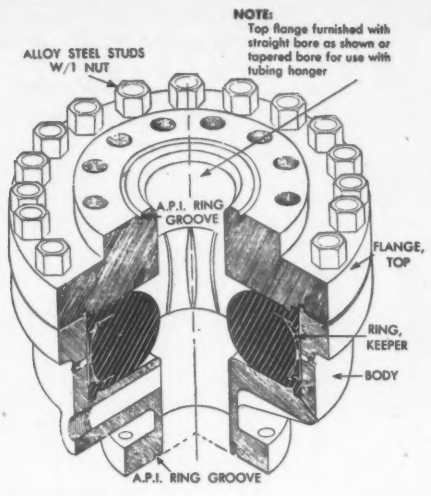
Fig. 7 includes a cross sectional view of the OCT type "J-1" blowout preventer with the conventional pack-off in place. The heavy upper ring on the body is forced open by lowering the packoff into the upper, tapered portion of the ring. After the packoff is in place, it is secured by a shoulder on the upper ring, after the ring is returned to its closed position by a spring. A heavy pin is furnished for holding the ring in closed position.

The manufacturer of this particular unit recommends it principally for use in conjunction with ram type preventers, for work-over hook-ups, and similar applications.

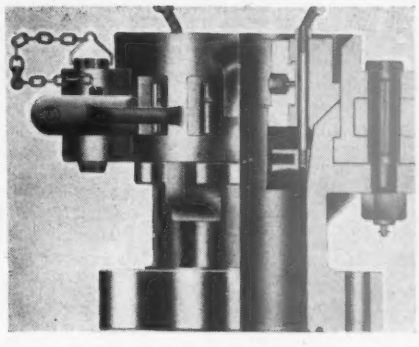
Flow Line Valves

Whenever a flow line, or mud return line, is taken out at a level below the rams of a preventer in a pressure control assembly, a valve must be provided to supplement those rams by closing the flow line. Most flowlines are relatively small as compared to the well bore, but, in general, the problems of design are similar to those of blowout preventer and master valve design.

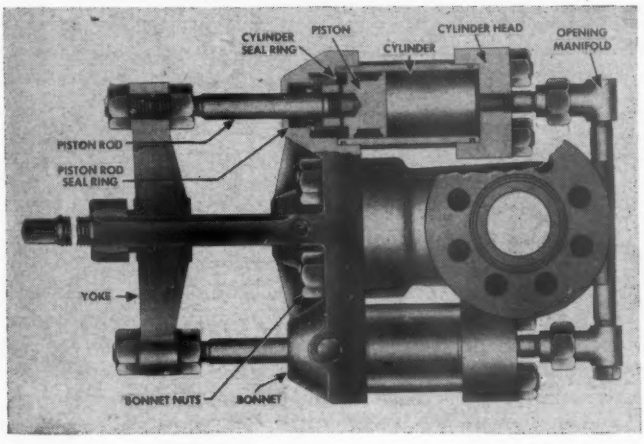
Ram Type Valves. Because of the similarity of the conditions of use just mentioned, it is natural that ram designs

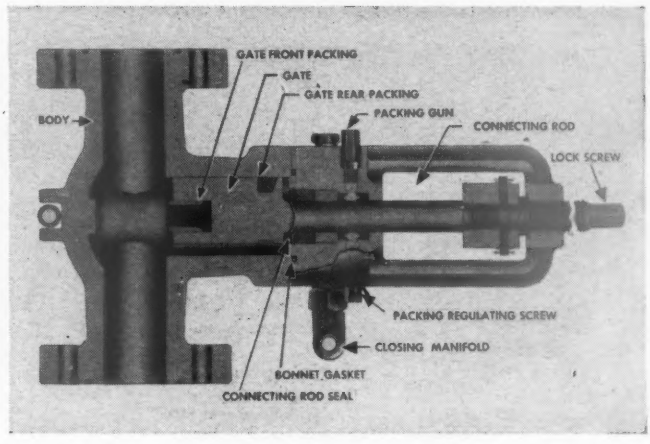

NOTE:
Top flange furnished with straight bore as shown or tapered bore for use with tubing hanger
ALLOY STEEL STUDS W/1 NUT
A.P.I. RING GROOVE
FLANGE, TOP
RING, KEEPER
BODY
A.P.I. RING GROOVE

Photos and cut away view, above, of Regan Torus.



Oil Center Tool Type J-1.





Cameron Type HCR flowline valve.

FIG. 7.

having a considerable volume of resilient packing should be used to some extent. In general, valves of this sort are more expensive to buy than conventional gate or plug valves, but are less expensive to maintain.

Cameron "HCR" Valve. Also illustrated in Fig. 7 is the Cameron Type "HCR" flowline valve, which is one of the most common in present day use. It is made in both four inch and six inch sizes. The primary difference between it and earlier ram type valves is that line pressure is bypassed to the rear of the ram. This reduces the force required to close the unit by a substantial amount, and allows the flow line pressure to hold the ram in the closed position.

Maintenance on this unit does not differ materially from that for the "QRC" blowout preventer.

Gate Type Flow Line Valves. There are only a few gate type valves used at present for flowline service, and these are usually used on assemblies for medium or low pressure in the areas of well defined pressures. Only two commonly used valves are designed primarily for service with abrasive fluids.

Cameron "Flex Seal" Mud Valves. Fig. 8 contains cross sections of the Cameron "Flex-Seal" mud valve which illustrate the resilient lining in the body which engages the gate to effect a seal. Lubrication and occasional disassembly and inspection ordinarily insure reasonable working conditions. This valve is most widely used for mud line manifolding.

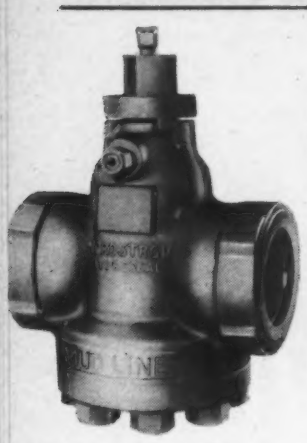
Edward "Mud Wonder" Mud Valve. Also coming into use on flow lines is the recently introduced Edward mud line valve. Mechanical features differ from those of the "Flex-Seal," but the "Mudwonder" employs a metal gate forced into a resilient lining for effecting a seal in a manner similar to that of the "Flex-Seal." Replacement of expendable parts is simple and fast with this valve.

Plug Type Flowline Valves. Several extremely well built, heavy, plug type valves are sometimes used for mud flow lines. Although such valves are more or less general purpose valves, they extensively employ hard facing materials and have accurately machined seating surfaces. They are seldom seen in sizes larger than three and four inches, and are often gear operated in view of the abrasive fluids and potentially high pressures.

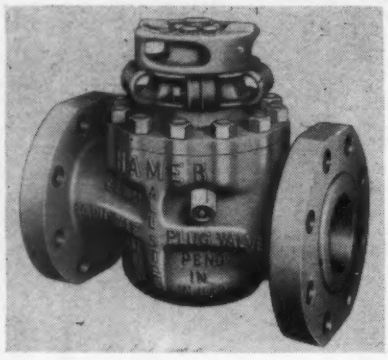
Kelly Cocks

Whenever anticipated formation pressures are greater than the maximum safe working pressure of a rotary hose, or perhaps a rotary swivel, it is usual to provide a valve of one sort or another in a rotary substitute which is made up between the kelly and the swivel. Such valves must be reasonably well balanced in order that no undesirable large forces are developed under rotation. Many of these valves are plug type, and many employ some resilient sealing material. One unit employs a rotating ram similar to the rotating ram blowout preventer previously described. This unit, together with another common model, is illustrated in Fig. 8.

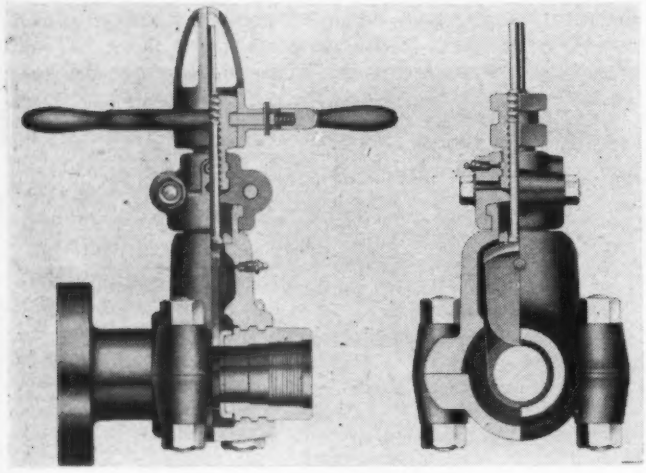
Maintenance on these units involves occasional dis-



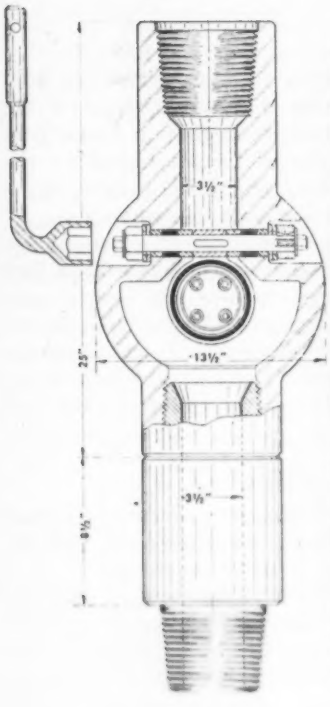
Rockwell-Nordstrom Hypreseal plug valve.



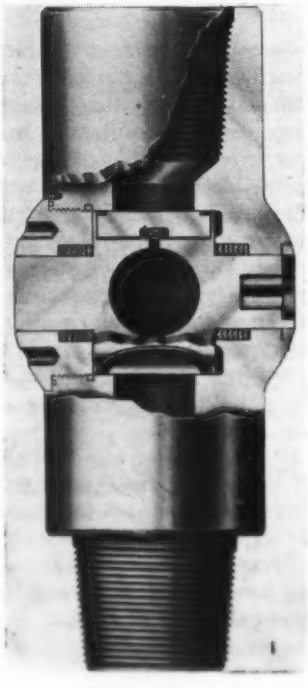
Hamer plug valve.



Cameron "Flex Seal" mud valves.



Omsco kelly cock.



Shaffer kelly cock.

FIG. 8.

assembly, inspection, cleaning, and repair. Manufacturers ordinarily furnish detail instructions for each specific unit.

Internal Blowout Preventers

Some work has been done in recent years towards the development of a tool which would float inside drill pipe on a difference in head between the inside and outside mud, and which would engage the inside of the drill pipe when its rate of rise in the pipe exceeded a predetermined value to effect a closure. It would be used ordinarily only during round trips. No unit of this type is known to be widely used.

Bolting and Gaskets

Bolting and gaskets used are usually standard items made and sold in strict accordance with API standard 6B, which describes the flanges; they are the universal connecting element. Material that does not meet this specification should be used only as a last resort.

Bolting should be maintained in a clean, rust-free condition with the nuts running freely on the stud bolts. Gaskets should be handled with care, and should be free from any surface defects, nicks, or rust. They should not be reused.

General Flange Maintenance

Since most leaks on pressure control assemblies occur at the connections between the various units, it is obvious that flange maintenance is as important as maintenance of the units. As mentioned before, the ring groove should be protected at all times with a light film of oil. If the joint is to be disassembled for a long period, a rust preventive applied before installing a wooden protector is worthwhile.

At the time a joint is made up, both the gasket and the groove should be perfectly clean except for the light film of oil, or very light grease. Grooves should never be cleaned with a wire brush. Resilient supplementary seals, just mentioned, aid in protecting the primary sealing surfaces, and in practice have reduced the incidence of flange leakage. Large amounts of grease in ring grooves can interfere with the proper engagement of the sealing surfaces and produce leakage long after the joint has been made.

Assembly Inspection

A great deal has been said about visual inspection in connection with the various components and with the connecting elements. While this type of inspection in connection with maintenance is invaluable, it must be understood that the combination of the various units of equipment amounts to an integration of specialized functions, so that the assembly acts more or less as a unit with more generalized or universal function. After assembly, a need for inspection and maintenance of the assembly as a whole exists.

Pressure Testing of Assemblies

Since the primary function of the assemblies discussed is to control pressure, fluid pressure testing and inspection for leakage is extremely important. The following statements should be considered carefully.

1. A planned margin of safety should be maintained. For example, if a pressure of say 3000 psi is thought possible, the assembly should be able to hold a predetermined higher pressure, without leakage, to provide some safety factor.
2. The fact that an assembly will hold a given test pressure today does not necessarily insure that it will not leak at some considerably lower pressure a week from today, under identical test conditions.
3. The ability of an assembly to hold a given pressure with mud does not mean it will hold as much with water; the ability to hold with water does not necessarily tell anything about the gas pressure which will cause leakage.

In view of these statements, it seems obvious that the

FILL YOUR CASING AUTOMATICALLY

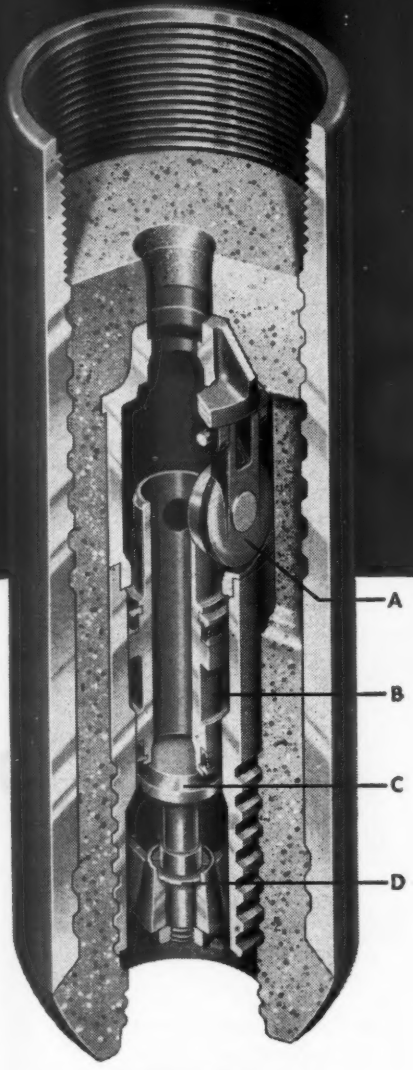
...from the bottom...while it's being run

with BAKER

• DIFFERENTIAL FILL-UP SHOES *and*
• DIFFERENTIAL FILL-UP COLLARS

Here's what DIFFERENTIAL FILL-UP Equipment does...

Permits the casing to *fill automatically from the bottom*, while it is being run, to within 90% of the fluid level of the annulus (using a shoe OR a collar)—or to within 81% of the fluid level of the annulus (using *both* a shoe AND a collar). In addition, a back-pressure valve is present to be used at the *discretion of the operator*, for "floating" or for cementing.



Baker DIFFERENTIAL FILL-UP Shoe, Product No. 1081.

A—Flapper Valve functions only at discretion of operator.
B—Sleeve Valve operates to control rate of flow and volume of "fill-up" fluid.
C—Sleeve Valve Seat.
D—Shear Ring is sheared. Flapper Valve now functions for floating or cementing.

Here's how Baker DIFFERENTIAL FILL-UP Equipment will aid you to avoid danger, increase rig efficiency, save valuable time and promote safety...

REDUCES THE DANGEROUS "RAM EFFECT" thus minimizing the hazard of breaking down a potential lost circulation zone.

SAVES COSTLY DRILLING MUD that might otherwise be lost to the formation due to the "ram effect."

MINIMIZES DAMAGE TO MUD CAKE on the wall of the hole. The majority of the fluid displaced as the casing string is lowered enters the casing instead of flowing up the annulus and causing possible damage to the mud cake.

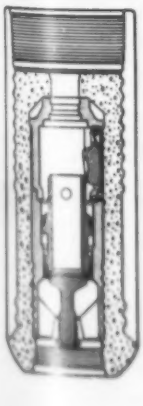
REDUCES DANGER OF STICKING CASING by reducing to a minimum the "no-motion time" formerly required to fill casing at the surface—extremely important when running casing in directional holes or sloughing formations.

SAVES ONE-HALF THE RUNNING-IN TIME plus the proven advantages of Baker Floating Equipment, including a back-pressure valve for cementing.

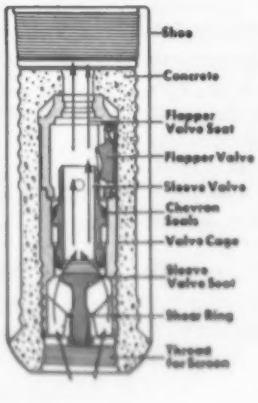
KEEPS THE RIG FLOOR CLEAN AND SAFE by eliminating the messy spill-over and splattering of mud present when casing is filled at the surface.

Ask any Baker representative or office for this new 16-page illustrated brochure...

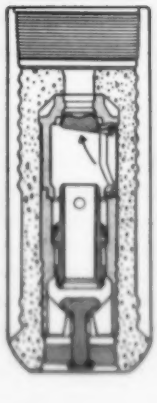
BAKER OIL TOOLS, INC., HOUSTON • LOS ANGELES • NEW YORK



When running-in, the Sleeve Valve is in closed position in contact with the Sleeve Valve Seat. When the Sleeve Valve is in this position, fluid entry into the casing from below the valve is effectively blocked. The Sleeve Valve will be in the closed position whenever the height of the fluid column in the casing (the fill) EXCEEDS 90% of the height of the fluid column in the annulus.



When the height of the fluid column in the casing (the fill) is LESS than 90% of the height of the fluid column in the annulus, the Sleeve Valve moves upward away from the Seat and permits fluid entry into the casing through the bottom of the FILL-UP Shoe. During the casing run, the Sleeve Valve opens and closes according to the pressures imposed on its top and bottom areas and thus automatically regulates the degree of fill.



When it is time for cementing, pressure of approximately 1,000 psi is built up in the casing to shear the Shear Ring that holds the Sleeve Valve Seat in the supporting vanes of the Valve Cage. The Sleeve Valve can then move downward sufficiently to release the spring-loaded Flapper Valve, and thereafter the FILL-UP Shoe functions as a conventional Float Shoe.

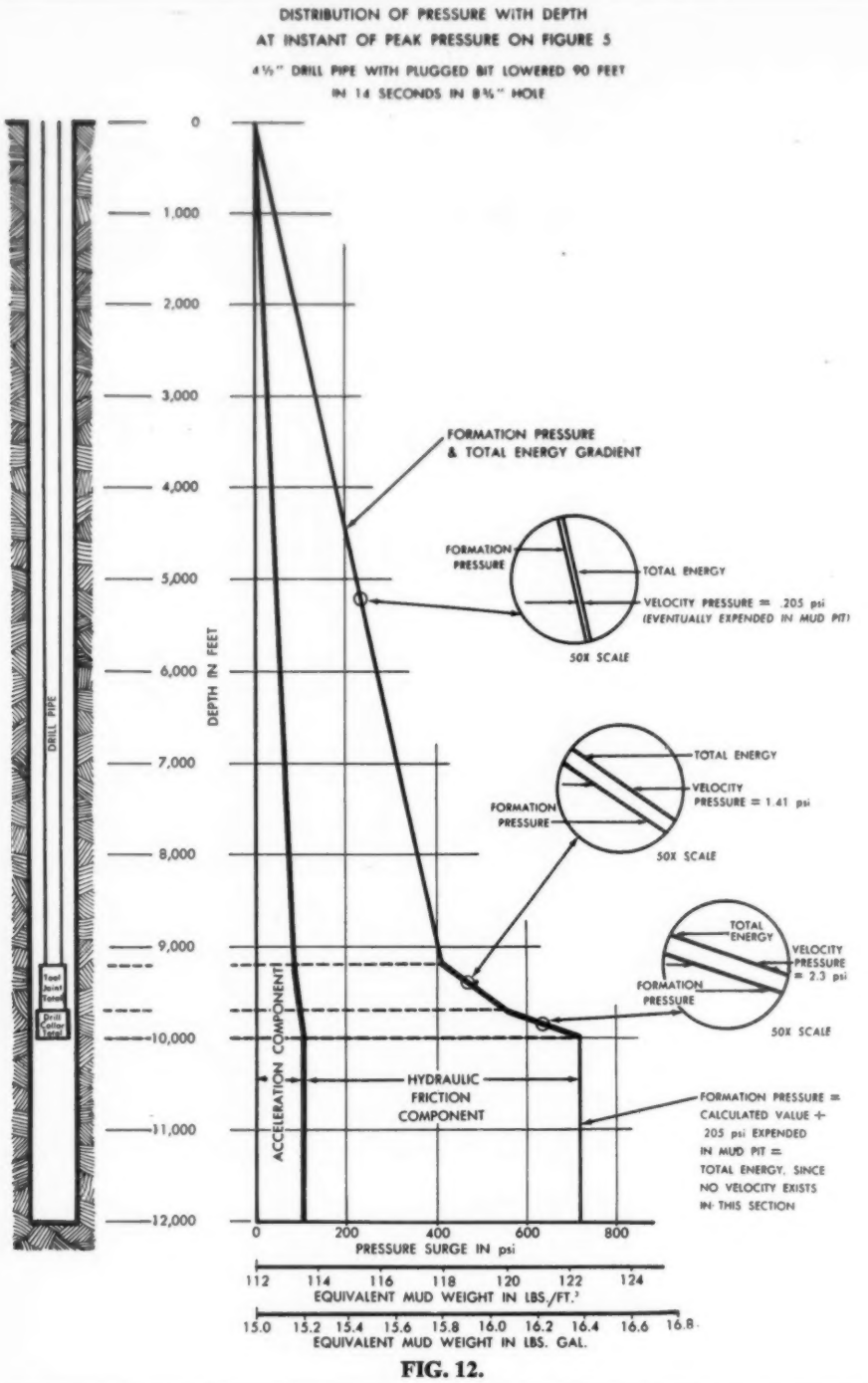


FIG. 12.

It is recommended that the following pressure-reduction practices be instituted as standard procedures, even where lost-circulation difficulties are not expected:

1. **Increase running or pulling times sufficiently to keep pressures safely above zonal hydrostatic pressure, but below the formation strength at all times.**
2. **Decrease the rate of acceleration or deceleration of the pipe through smoother brake handling and earlier use of the hydromatic brake.**
3. **Use bottom fill devices (wherever they are feasible commensurate with other problems that might exist) to relieve annulus volumes by internal filling.**
4. **Increase clearances wherever possible. (Although this concept is affected by so many other economic factors that the recommendation of changing programs would be inadvisable on this basis alone, there is a point of decreased clearance at which the bottom-hole pressures will begin a very rapid upward swing. This should definitely carry some weight along with the other economic factors determining a given drill pipe, casing, and open-hole relationship.)**
5. **Care should also be used with projections above pipe size such as oversize drill collars, and drill pipe protectors, or improperly designed centering and scratching equipment run on casing. These projections can compound pressure build-ups, particularly if they should create excessive pressure losses because of local turbulence and eddies.**
6. **The practice of spudding back through previously drilled formations, using high rates of pumping as well as high rates of pipe acceleration and deceleration, should be definitely controlled.**

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GAS IN ARCTIC CIRCLE

Although the United States probably is the greatest producer of natural gas in the world, geologists continue to discover this fuel in remote corners of the earth. An extensive deposit of oil was found in Umiat, in the Naval Petroleum Reserve in the Arctic Circle. One large natural gas field also was found there. However, because of the expense involved in transporting oil and natural gas from Northern Alaska, the Navy believes that at least four fields that could produce at least 100,000 barrels daily would be needed to make the venture profitable.

XUM

BLOWOUT PREVENTERS

MARVIN R. JONES*

EXPERIENCE has proved that mechanical equipment must be used to supplement the hydraulic system used to control formation pressures encountered in rotary drilling operations.

A possible assembly of equipment designed to effect such control is shown in Fig. 1. Starting from the bottom, the elements shown are:

1. A combination unit including a blowout preventer and a master valve.
2. A drilling spool.
3. A blowout preventer.
4. A blowout preventer.

From the drilling spool, to the right, is shown a flow line valve and a flow line. To the left are wing valves and a choke. Not shown in the figure but necessary for the operation of the equipment shown are a source of operating pressure and a control manifold for directing that pressure.

There is no standard assembly, and the possible variations are almost infinite. Special arrangements, and special equipment are used to meet various special conditions, but operators differ widely on what is the best hook-up.

Function of Elements

A blowout preventer is a valve designed to close off the annular passage formed between a large pipe to which it is attached, and a smaller pipe contained inside the large one. They are required to seal around pipe which may be moved, which may have a rough outer surface and which may be submerged in a highly abrasive fluid.

A master valve is simply one designed to close a passage formed by the extension of a well casing or tubing. In present day practice, most master valves used for drilling are simply standard blowout preventers equipped with closing members adapted to close an open hole.

Drilling spools are fittings used to provide operating space between elements on the one hand, and access to the well bore on the other. Many assemblies do not use spools, using arrangements providing operating space, and units having side outlets for access.

Flow line valves are similar in function to master valves, being employed to close lateral passages that are usually smaller than the well bore, under conditions much the same as those with which the master valve operates. Here again, many assemblies are so arranged that no flow line valve is required, with the return flow of mud coming away from the well bore above the top preventer.

A wing valve is similar again to the two previously mentioned valves; it is used to close the passage between the well bore and the choke.

The function of the choke is to throttle the return flow of mud when that flow is caused by well pressures over which operator has no control.

Besides the equipment shown, numerous other units are commonly used from time to time to control pressures in the well bore. Some of these seals are what could be called "working pack-offs" as compared to the emergency pack-offs; and they are used to control pressures developed intentionally at the surface of the well. Such cases occur when it is necessary for some reason to use a circulating fluid whose weight only partially offsets the formation pressure. They also occur when it is necessary to apply pressure to the well bore during operations to achieve some particular result.

Other equipment not shown includes such elements as drill stem float valves, kelly cocks, and internal blowout preventers of various types.

Summed up, control assemblies of this sort are used primarily to control formation pressures in a well bore during drilling operations when it is either not possible or not practical to control them entirely by hydraulic means, that is by weighting drilling fluid.

Pressure Control Assembly

For the purpose of a more specific examination of the various elements assembled to control the pressures we have discussed, it is possible to consider two general groups: primary equipment and secondary equipment.

Elements classified as primary equipment can be described as those designed and used for the purpose of holding safely whatever pressure the formation may be able to impose on the assembly it is a part of.

As stated previously, master valves are those units used to close the open well bore and hold whatever pressures may be developed. In the past, conventional steel gate valves were used for this purpose, but at the present time, the large majority of master valves are blowout preventers with rams adapted to make a closure on the open hole. This has come about because of the necessity of making a leak tight closure under extremely adverse conditions and because of the necessity of making operating time as short

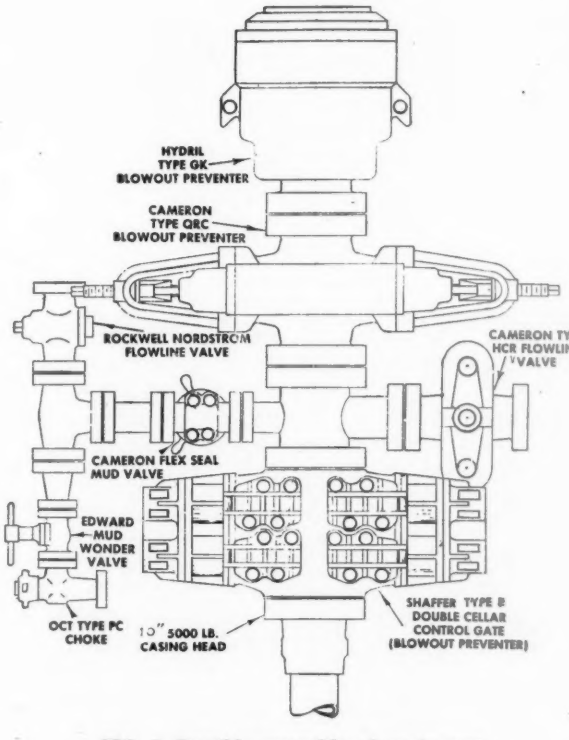

HYDRIL TYPE GK BLOWOUT PREVENTER
CAMERON TYPE QRC BLOWOUT PREVENTER
ROCKWELL NORDSTROM FLOWLINE VALVE
CAMERON TYPE HCR FLOWLINE VALVE
CAMERON FLEX SEAL MUD VALVE
EDWARD MUD WONDER VALVE
OCT TYPE PC CHOKE
10" 5000 LB. CASING HEAD
SHAFFER TYPE B DOUBLE CELLAR CONTROL GATE (BLOWOUT PREVENTER)

FIG. 1. Possible assembly of equipment.

*Petroleum Mechanical Development Company, Houston, Texas.

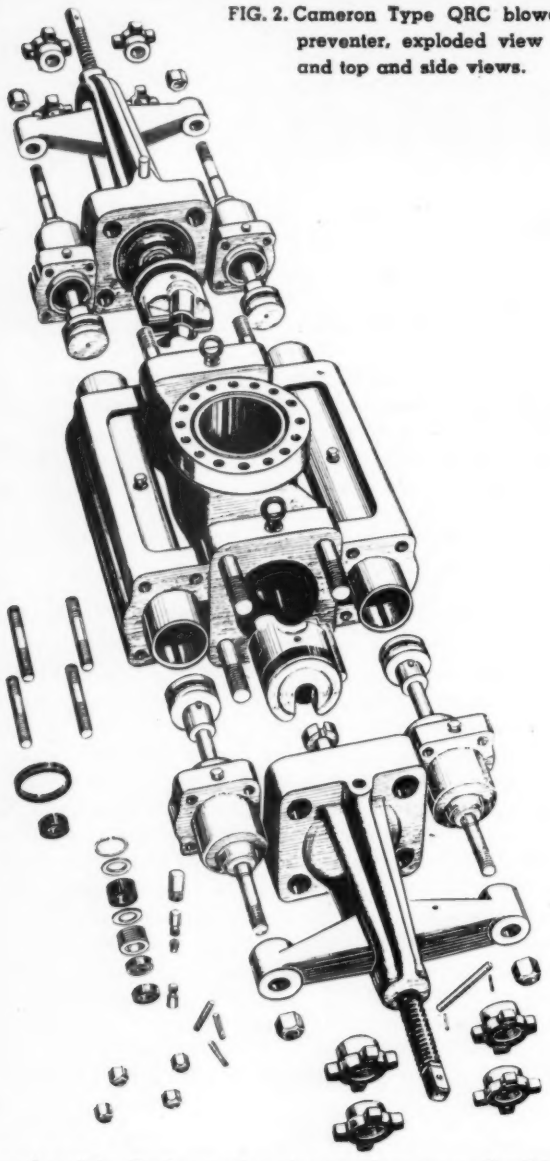
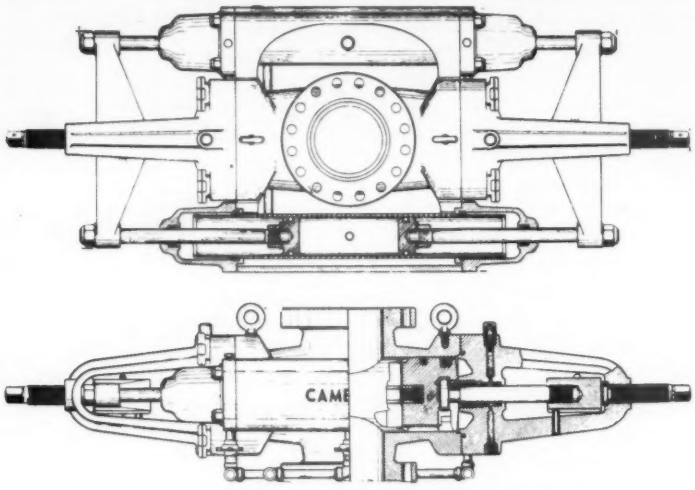


FIG. 2. Cameron Type QRC blowout preventer, exploded view and top and side views.



as possible. Such practice also employs more flexible equipment. For some years two or three special types of master valve were used, and some few of these valves are still in use. The practice is not common, however, and the discussion on blowout preventers will cover the equipment most usually used for master valves.

Blowout Preventers

API Standard 6E states our definition of a blowout preventer in these words: "A blowout preventer is a unit attached to the casing or to a unit of wellhead equipment installed thereon for the purpose of controlling pressures in the annular space between the casing and an inner string of pipe during drilling and completion operations." This definition is not quite broad enough to cover all blowout preventers in the sense that the term is sometimes used to describe units used with wire rope, lines, or sucker rods; or may be applied to devices used inside drill pipe. The following remarks are limited to the meaning of the definition.

Ram Type Preventers

Ram type preventers of one sort or another form the basic element in almost all pressure control assemblies today. In this sense, a ram is defined by the standard just quoted as "a unit retractable from the bore of a wellhead or blowout preventer, which in its extended position engages a pipe to effect a seal in the annular space between the well head or blowout preventer, and may provide a means of support for the pipe." These rams described are customarily retracted by sliding or by rotating them out of engagement.

Two types of ram construction are popular: cylindrical and flat. Only one unit using cylindrical rams adapted to slide in and out of round bores opposing each other at right angles to the axis of the wellbore is currently extensively manufactured and used.

Cameron Type "QRC" Blowout Preventer

Fig. 2 illustrates Cameron Type QRC, which has these features considered to be advantages and disadvantages:

Advantages

1. It has high pressure capacity.
2. It operates reliably with minimum maintenance.
3. Maintenance is reasonable in cost.
4. Its overall height is low compared to most annular preventers.
5. It is simple.
6. Ram change is easy.
7. Rams are interchangeable between pressure ratings.
8. Rams have high pipe hanging capacity.
9. Ram front packings have high wear volume.
10. Operating speed is fast.
11. Well pressure tightens ram seal.

Disadvantages

1. Overall height is more than that of flat ram preventers.
2. Corresponding rams and packing are required for each pipe size.
3. Preventer can be installed upside down.
4. Too much cellar space is required for ram change.
5. It is difficult to test between rams as test pressures tend to make lower rams leak by forcing them open.
6. Two preventers are required to work pipe in or out of the hole under pressure.
7. QRC is heavy as compared with flat ram units.
8. Piston and operating rods are exposed to dirt and damage.
9. It cannot be opened manually.
10. Close fitting rams require more maintenance to prevent sticking than do looser fitting ones.

Care and Maintenance. Maintenance of QRC preventers is simple. In use, any ram type preventer should be operated at least once each day and better yet, once each tour. If more than 150 psi operating pressure is required, the preventer should be disassembled in conformance with the manufacturer's manual and the reason for hard operation ascertained at the first opportunity. Some of the reasons for hard operation are damage to the rods, dirt or other foreign material, and misalignment. Rust on the ram bore or on the

ram, and swollen packing can also interfere with normal operation.

During each disassembly, all working parts should be cleaned and lubricated with the proper lubricant.

It is a highly profitable practice to disassemble, clean, lubricate, and reassemble each preventer at regular periods, perhaps at moving time, and always before storage periods. Particular attention should be paid to the flanges at the time of any disassembly of units. Probably more serious leaks have developed between flanged joints than at all other critical points combined. Ring grooves should be cleaned with a solvent, should be greased, and should be fitted with a wooden protector when not in use. Grooves in use should be protected with a light film of oil or light grease. Damaged grooves should be sent in to the manufacturer for repair.

The manufacturer's care and maintenance manual should be used for reference to all details of maintenance, and should be available to well crews at all times when the preventer is in use.

Flat Ram Preventers

Several makes of preventers employing flat rams are now popular. Most preventers of this type use designs in which the rams slide in and out of opposing ram bores in much the same fashion as the rams of the QRC do. One unit in this group, however, rotates the rams into engagement about a horizontal axis at the upper rear of the ram.

Shaffer Type "B" Blowout Preventer

FIG. 3 shows various views of the Shaffer Type "B" preventer, called by the manufacturer a "hydraulic cellar control gate." This unit is one of the latest in a long line of flat ram preventers which have been extensively used. The "double gate" model, ordinarily using one set of "blind rams" adapted to close on open hole, and one set of "pipe rams" adapted to engage some particular size of pipe is most popular and is discussed here.

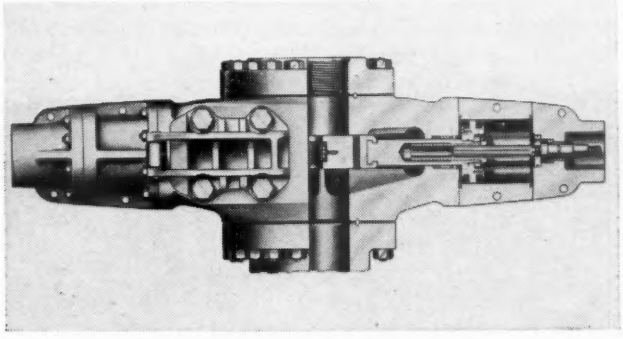
Although it is obvious that many of the advantages and disadvantages (or limitations) are identical to those of the QRC, users have mentioned some of the following as important features in their estimation:

Advantages

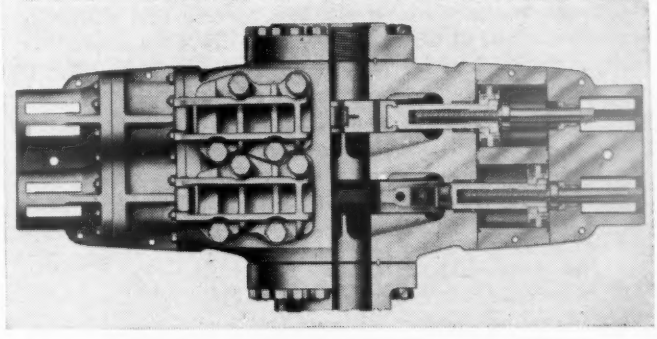
1. Its overall height is less than is possible or practical with cylindrical ram preventers.
2. Ram change is extremely easy and requires very little space.
3. Rams can be handled by hand.
4. Operating screw and rods are not exposed.
5. It is compact and light, as compared with round ram preventers.
6. Integral skids make for easy handling.
7. Fairly easy opening under pressure is often convenient.
8. Double construction eliminates one flanged connection.
9. Loose fit between rams and body in retracted position reduces danger of rams sticking.
10. Maintenance is very simple and inexpensive.
11. Rams have high pipe hanging capacity.
12. Ram chambers drain well.
13. Has high pressure capacity.
14. Lower rams can be changed without removal of upper rams.

Disadvantages

1. Unit cannot be opened manually.
2. Double design does not lend itself to maximum flexibility in the location of flowlines, choke manifolds, fill up lines or the like. (Single models do.)
3. Studded flanges are more difficult to handle without damage (to studs) on large units of equipment.
4. Corresponding rams and packing are required for each pipe size.



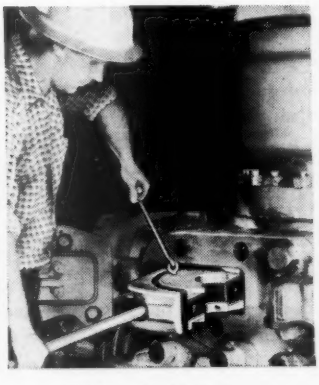
Shaffer Type B hydraulic single cellar control gate. Non-rising stem.



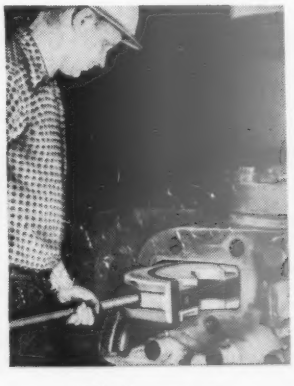
Shaffer Type E hydraulic double cellar control gate. Rising stem.

Loosen screw cap.

Open doors.



Slide out old ram.



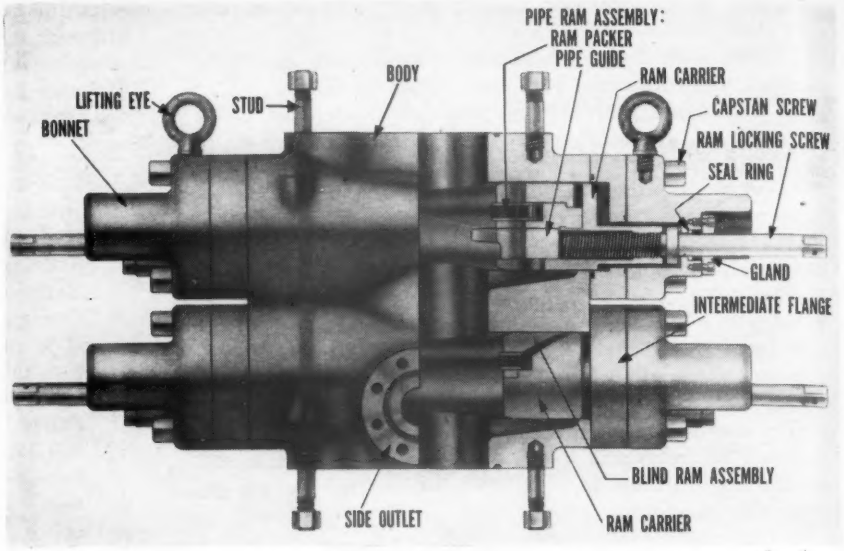
Slide in new ram.

FIG. 3. SHAFFER CONTROL GATES.

5. Two preventers are required for working pipe into or out of the hole under pressure.

Care and Maintenance. This unit should be operated once every day during drilling operations. If any increase in operating pressure is noticed, the rams should be removed at the first opportunity and should be cleaned and inspected. Ram recesses should be thoroughly washed and checked for dirt or nicks. If after correcting any conditions found, and if after operating several times, the preventer still requires too much pressure to operate, a company service man should be asked to check the unit.

In addition to the care and precautions mentioned in connection with the QRC flanges, studs should be protected from mechanical and corrosive types of damage while in transit or storage.



Cameron Type SS.

Shaffer Type "E" Blowout Preventer

Fig. 3 also shows a sectional view of the Shaffer Type "E" double gate preventer. Like the Type "B," it is available in either the double or single gate style, at the buyer's option.

The primary difference between the Type "E" and Type "B" preventers lies in the locking screw design. On the Type "E" preventers the screw moves in and out with the rams, whereas the others have non-rising stems.

No portion of either locking screw is exposed to well fluid or external mechanical damage.

General operating features, advantages and disadvantages, and maintenance required are the same as for the Type "B."

Cameron Type "SS" Preventer

This preventer is relatively new, having first made an appearance in Gulf Coast and West Texas fields during the early summer of 1953. Very little user comment is available, but examined in the light of comment provided on the two previous units discussed, it seems likely that the features listed will be considered desirable:

1. Its overall height is low as compared to round ram preventers.
2. It is compact and light as compared to round ram preventers.
3. Ram change is easy.
4. Operating rods and screws are not exposed to exterior damage. (They are exposed to well fluids.)
5. Double construction eliminates one flanged connection.
6. Large volume of ram front packing gives long wear.
7. No fluid lines are exposed.
8. Maintenance is simple and inexpensive.
9. Well pressure tightens ram seal.
10. Rams have high pipe hanging capacity.

It is reasonable to believe that the limitations and disadvantages of a basic nature will be for all practical purposes similar to those listed for Shaffer Type "B."

Care and Maintenance. Operate the "SS" preventer at least once a day while it is in use. Once a tour is better. Remove, clean, and inspect the rams if operating pressures go above 300 psi, or if they suddenly increase.

When rams and bores in good condition do not provide easy operation, use the manufacturer's manual as a guide to disassemble the cylinders for inspection and repair. Lubricate the unit as directed.

Release four capstan screws on each bonnet.

Operating pressure opens bonnets and withdraws ram assemblies.

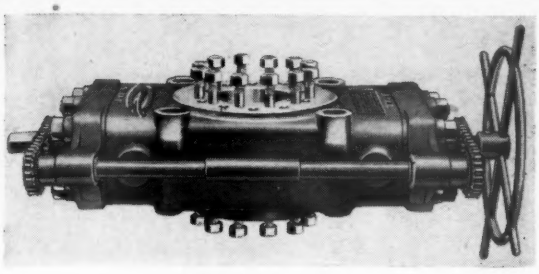
Ram may then be easily lifted from the preventer.

Pipe centering guide is also easily lifted out of preventer.

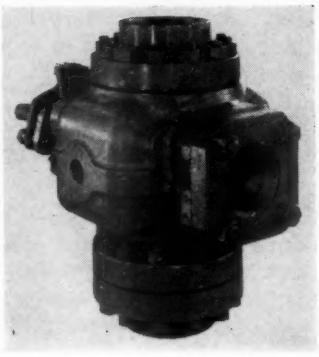
FIG. 4. CAMERON BLOWOUT PREVENTER

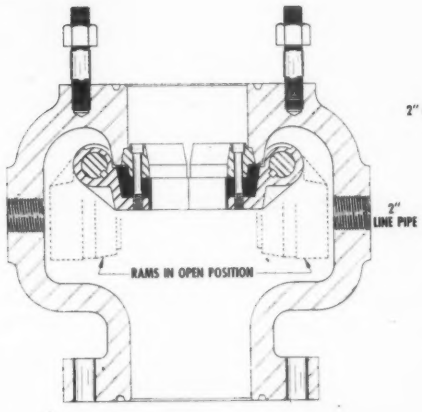
Guiberson Type "A" Blowout Preventer

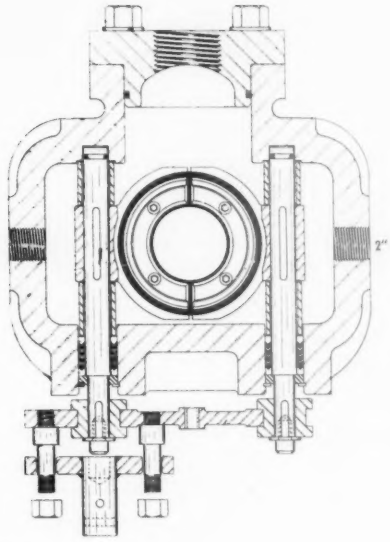
Fig. 5 illustrates another fairly recent development. This unit is now used mostly for completions, recompletions, workover, and shallow drilling operations. No sizes larger than eight inch nominal have been seen, nor are large sizes listed in the manufacturer's catalogs. A unique arrangement is provided for connecting two of these units together to form a double unit comparable in overall height to other flat ram double units. One other feature is the provision of extra stud holes so that users may bolt the standard



Guiberson Type A







Omsco blowout preventer using rotating rams — photo and two cross sections.

FIG. 5.

body, made in only the 3000 psi cwp rating, to either the API series 600 or series 900 flanges without the use of adapters.

Although this unit has met with success in its introduction, no considerable amount of generally conceded opinion is found. Here again it is reasonable to believe that the general comment made on older equipment of the same general type will apply to some degree to this unit.

Care and Maintenance. Maintenance on this unit appears to be very reasonable and simple. Daily operation to insure maintenance of satisfactory condition, and cleaning and lubricating at regular intervals seem to be required in about the same degree as other ram type preventers. Yearly disassembly, cleaning, part inspection, repair, and replacement represents a wise investment on any unit of primary pressure control equipment.

Omsco Blowout Preventer

Fig. 5 also shows the Omsco blowout preventer, which is a highly popular unit using rotating rams. One model sometimes seen, but not shown, provides a third ram located ninety degrees away from the two pipe rams. This ram is blind and is used by itself to close the bore of the body when no pipe is in the hole. It allows the design of a preventer which combines the advantages of an overall height between that of round ram preventers and that of flat ram preventers, together with through bolted flanges.

Although these units are not new, it is impossible to develop enough comment to list the opinions expressed as consensus at this time. One remark worth consideration, however, was that ram packing pressure is developed entirely by well bore pressure. This precludes developing excessive packing pressures which would result in excessive wear against moving pipe. On the other hand, it is possible to conceive of occasions when higher packing pressure than that developed by wellbore pressure would be desirable. One other comment was that rams held pressure in only one direction, and that it was necessary to equalize pressures to open the preventer.

Care and Maintenance. Little is required in the way of maintenance on the Omsco preventer. Regular operation, cleaning and inspection will normally insure satisfactory operation.

Miscellaneous Ram Type Preventers

A small number of ram type preventers are being used other than those just described. Many of these are becoming obsolete and are used in non-critical installations while some are no longer manufactured. In all cases, however, these units are similar in general respects to one or more of the units described. No pressure operated ram type units in this group are known.

Advantages of Ram Type Preventers. Compared to other types of blowout preventers, ram types are generally conceded to afford compact size, low first cost, low maintenance costs, high pressure capacities, reliable operation and desirable operating characteristics.

Limitations of Ram Type Preventers. The primary limitation of the ram type preventers currently available is that ram and ram front packings must correspond in size to the pipe they engage.

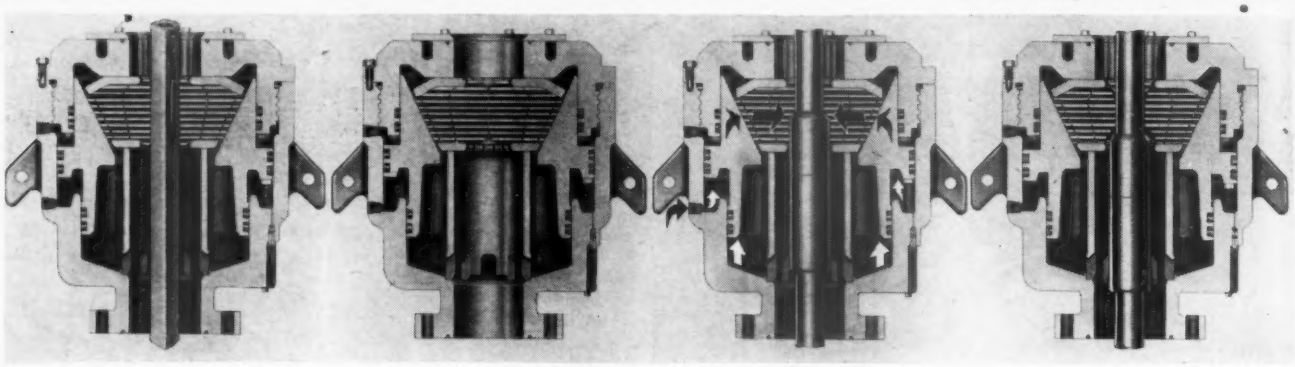
Annular Type Blowout Preventers

A purely arbitrary name for the type of blowout preventer, which uses a ring of packing material supported in some fashion by metal to close the annulus between the well pipe and the bore of the head is "Annular Type." Several types of units fall into this general classification.

Contractible Annular Type. The most popular type of annular preventer construction uses a ring of packing material with suitable reinforcement. This ring has the same inner diameter as the body of the preventer and remains in place ready for use at all times. Means are provided to constrict this ring until its inner diameter is small enough to engage and seal on a pipe, or even to effect a total closure on an open hole.

Hydril Type "GK" Blowout Preventer

Fig. 6 shows a cut-away view of the Hydril type "GK" blowout preventer. To operate this unit, liquid under pres-



Shows tight pack-off on kelly for holding high well pressures.

Pack-off on open hole safely holds well pressures equal to rated working pressure of preventer.

Shows tight pack-off for holding high well pressure and for preventing upward movement of pipe.

Shows controlled pack-off for easy stripping of tool joints.

FIG. 6. HYDRIL TYPE GK.

sure is introduced under the piston whose upper, inner surface is conical. Steel reinforcement in the packing element prevents upper movement of the element so that the conical surface of the piston forces the element to constrict.

Advantages

1. It seals on whatever size or shape is in the hole.
2. It seals on open hole.
3. One preventer can be used to work pipe into or out of the hole under pressure.
4. It reduces the number of preventers required.
5. It reduces the danger of pulling tool joints into the sealing element.
6. It is simple.
7. Packing elements have high wear volume.
8. Well pressure tightens seal.
9. Wear surface is under high circumferential compression.

Disadvantages

1. It costs more than some ram type preventers.
2. It is taller than ram type preventers.
3. It cannot be operated by hand.
4. It must be repacked from the top.
5. Time required for repacking is greater than for ram type preventers.

Care and Maintenance. Operation of the preventer periodically (two or three times a week is ordinarily adequate) insures that the unit will be in good operating condition when needed. It is not desirable in these operations to effect a closure on the open hole very often since the practice might produce some set in the packing which would keep it from opening to its full original bore.

When any positive increase is noticed in the pressure required to operate this unit, or when more than about 1300 psi is required to effect a complete closure on the open hole, the unit should be disassembled, cleaned, inspected, and defective parts should be repaired or replaced. Particular care should be taken to see that as little dirt and sand as possible is allowed to find its way into the operating cylinder, and the cylinder should be cleaned well at each disassembly.

Regan Types "K" and Torus Blowout Preventers

The Regan types "K" and Torus blowout preventers, as shown in Fig. 7, differ from the Hydril preventers in that the packing element is forced into sealing contact with the inner pipe by the direct action of a hydraulic fluid. Such a design is extremely simple and should be free of any tendency to stick. It has the ability to seal on all sizes and shapes of objects and can be used to work pipe with controlled operating pressure. No actual experience of any extent is available on the Gulf Coast, but it seems possible that the packing might have some tendency toward cold flow under higher pressures over extended periods of time. Far northern users of annular equipment have suggested use of flow lines above annular packings since low temperatures make for difficult operation and the mud returns provide some heat.

At the time of writing, the Torus preventer is a fairly recent development whose compact design seems to represent its most substantial improvement over its predecessors, together with the fact that it seems to have higher pressure capacity.

Care and Maintenance. Almost no maintenance is required to keep these units in safe condition. They should be operated and inspected periodically, and only pack-offs in reasonably good condition should be used. Normal protection of parts, particularly flanges, is about all the other maintenance required.

"Hosmer" Type Annular Blowout Preventers

One of the earliest approaches to the problem of closing the annular space between a well pipe and a casing was that of providing a split ring of packing and reinforcement which could be latched around the pipe and lowered to and secured in a special head. A considerable number of such units are presently being used, but only one type is being manufactured in any quantity.

OCT Type "J-1" Blowout Preventer

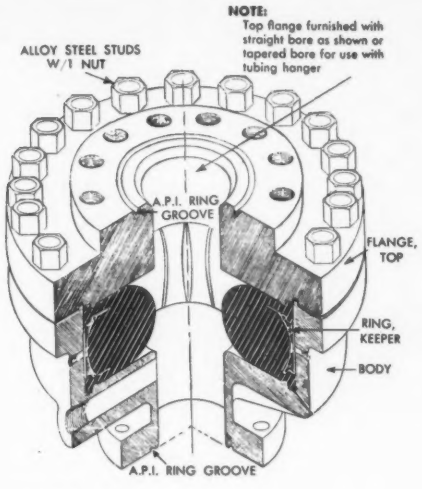
Fig. 7 includes a cross sectional view of the OCT type "J-1" blowout preventer with the conventional pack-off in place. The heavy upper ring on the body is forced open by lowering the packoff into the upper, tapered portion of the ring. After the packoff is in place, it is secured by a shoulder on the upper ring, after the ring is returned to its closed position by a spring. A heavy pin is furnished for holding the ring in closed position.

The manufacturer of this particular unit recommends it principally for use in conjunction with ram type preventers, for work-over hook-ups, and similar applications.

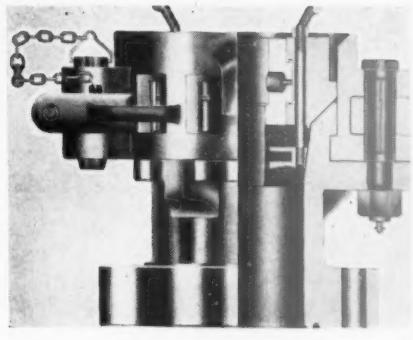
Flow Line Valves

Whenever a flow line, or mud return line, is taken out at a level below the rams of a preventer in a pressure control assembly, a valve must be provided to supplement those rams by closing the flow line. Most flowlines are relatively small as compared to the well bore, but, in general, the problems of design are similar to those of blowout preventer and master valve design.

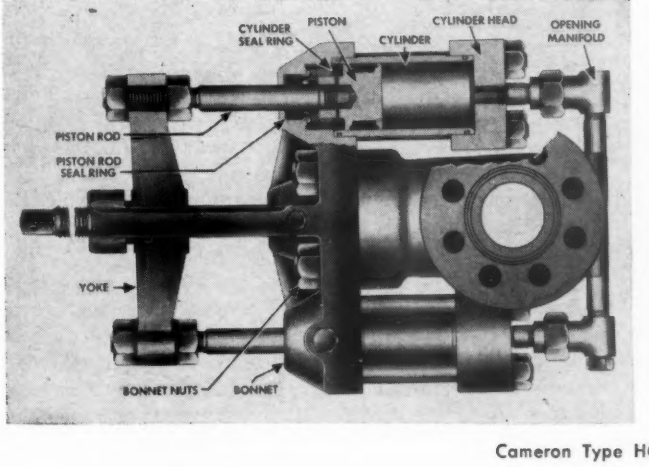
Ram Type Valves. Because of the similarity of the conditions of use just mentioned, it is natural that ram designs

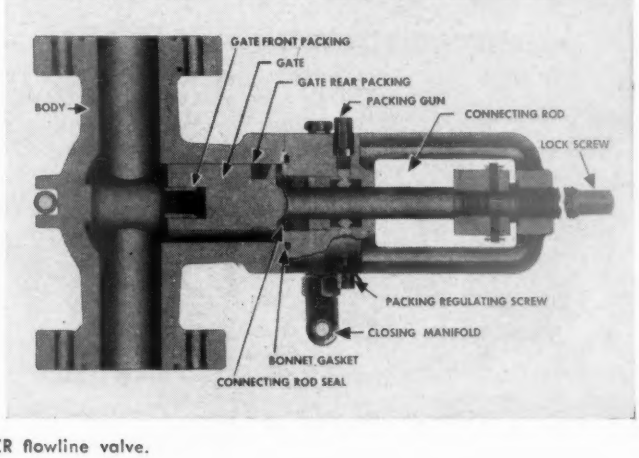

NOTE:
Top flange furnished with straight bore as shown or tapered bore for use with tubing hanger
ALLOY STEEL STUDS W/1 NUT
A.P.I. RING GROOVE
FLANGE, TOP
RING, KEEPER
BODY
A.P.I. RING GROOVE

Photos and cut away view, above, of Regan Torus.



Oil Center Tool Type J-1.





Cameron Type HCR flowline valve.

FIG. 7.

having a considerable volume of resilient packing should be used to some extent. In general, valves of this sort are more expensive to buy than conventional gate or plug valves, but are less expensive to maintain.

Cameron "HCR" Valve. Also illustrated in Fig. 7 is the Cameron Type "HCR" flowline valve, which is one of the most common in present day use. It is made in both four inch and six inch sizes. The primary difference between it and earlier ram type valves is that line pressure is bypassed to the rear of the ram. This reduces the force required to close the unit by a substantial amount, and allows the flow line pressure to hold the ram in the closed position.

Maintenance on this unit does not differ materially from that for the "QRC" blowout preventer.

Gate Type Flow Line Valves. There are only a few gate type valves used at present for flowline service, and these are usually used on assemblies for medium or low pressure in the areas of well defined pressures. Only two commonly used valves are designed primarily for service with abrasive fluids.

Cameron "Flex Seal" Mud Valves. Fig. 8 contains cross sections of the Cameron "Flex-Seal" mud valve which illustrate the resilient lining in the body which engages the gate to effect a seal. Lubrication and occasional disassembly and inspection ordinarily insure reasonable working conditions. This valve is most widely used for mud line manifolding.

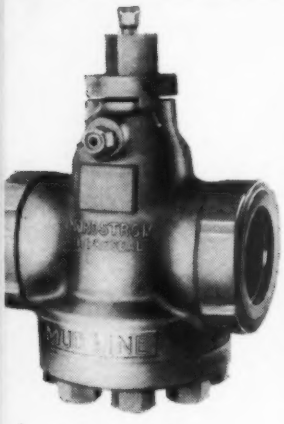
Edward "Mud Wonder" Mud Valve. Also coming into use on flow lines is the recently introduced Edward mud line valve. Mechanical features differ from those of the "Flex-Seal," but the "Mudwonder" employs a metal gate forced into a resilient lining for effecting a seal in a manner similar to that of the "Flex-Seal." Replacement of expendable parts is simple and fast with this valve.

Plug Type Flowline Valves. Several extremely well built, heavy, plug type valves are sometimes used for mud flow lines. Although such valves are more or less general purpose valves, they extensively employ hard facing materials and have accurately machined seating surfaces. They are seldom seen in sizes larger than three and four inches, and are often gear operated in view of the abrasive fluids and potentially high pressures.

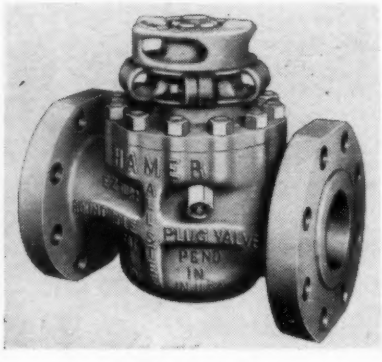
Kelly Cocks

Whenever anticipated formation pressures are greater than the maximum safe working pressure of a rotary hose, or perhaps a rotary swivel, it is usual to provide a valve of one sort or another in a rotary substitute which is made up between the kelly and the swivel. Such valves must be reasonably well balanced in order that no undesirable large forces are developed under rotation. Many of these valves are plug type, and many employ some resilient sealing material. One unit employs a rotating ram similar to the rotating ram blowout preventer previously described. This unit, together with another common model, is illustrated in Fig. 8.

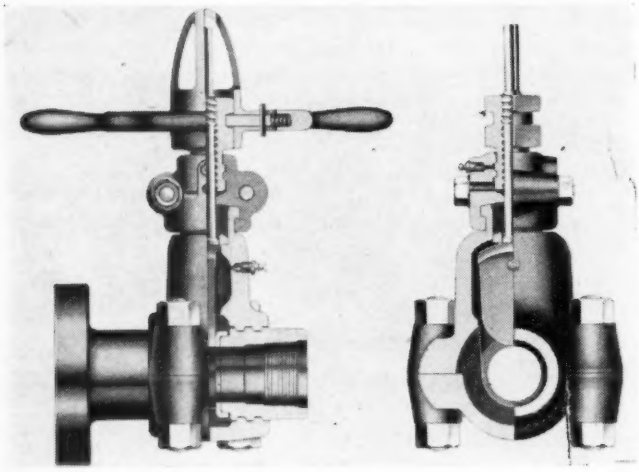
Maintenance on these units involves occasional dis-



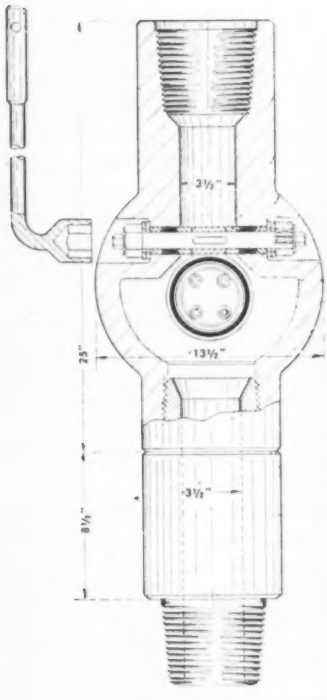
Rockwell-Nordstrom Hypreseal plug valve.



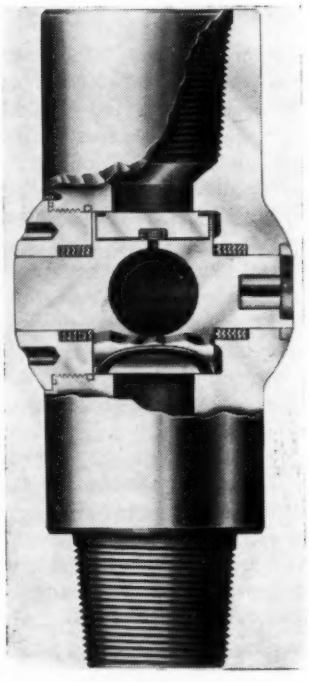
Hamer plug valve.



Cameron "Flex Seal" mud valves.



Omsco kelly cock.



Shaffer kelly cock.

FIG. 8.

assembly, inspection, cleaning, and repair. Manufacturers ordinarily furnish detail instructions for each specific unit.

Internal Blowout Preventers

Some work has been done in recent years towards the development of a tool which would float inside drill pipe on a difference in head between the inside and outside mud, and which would engage the inside of the drill pipe when its rate of rise in the pipe exceeded a predetermined value to effect a closure. It would be used ordinarily only during round trips. No unit of this type is known to be widely used.

Bolting and Gaskets

Bolting and gaskets used are usually standard items made and sold in strict accordance with API standard 6B, which describes the flanges; they are the universal connecting element. Material that does not meet this specification should be used only as a last resort.

Bolting should be maintained in a clean, rust-free condition with the nuts running freely on the stud bolts. Gaskets should be handled with care, and should be free from any surface defects, nicks, or rust. They should not be reused.

General Flange Maintenance

Since most leaks on pressure control assemblies occur at the connections between the various units, it is obvious that flange maintenance is as important as maintenance of the units. As mentioned before, the ring groove should be protected at all times with a light film of oil. If the joint is to be disassembled for a long period, a rust preventive applied before installing a wooden protector is worthwhile.

At the time a joint is made up, both the gasket and the groove should be perfectly clean except for the light film of oil, or very light grease. Grooves should never be cleaned with a wire brush. Resilient supplementary seals, just mentioned, aid in protecting the primary sealing surfaces, and in practice have reduced the incidence of flange leakage. Large amounts of grease in ring grooves can interfere with the proper engagement of the sealing surfaces and produce leakage long after the joint has been made.

Assembly Inspection

A great deal has been said about visual inspection in connection with the various components and with the connecting elements. While this type of inspection in connection with maintenance is invaluable, it must be understood that the combination of the various units of equipment amounts to an integration of specialized functions, so that the assembly acts more or less as a unit with more generalized or universal function. After assembly, a need for inspection and maintenance of the assembly as a whole exists.

Pressure Testing of Assemblies

Since the primary function of the assemblies discussed is to control pressure, fluid pressure testing and inspection for leakage is extremely important. The following statements should be considered carefully.

1. A planned margin of safety should be maintained. For example, if a pressure of say 3000 psi is thought possible, the assembly should be able to hold a predetermined higher pressure, without leakage, to provide some safety factor.
2. The fact that an assembly will hold a given test pressure today does not necessarily insure that it will not leak at some considerably lower pressure a week from today, under identical test conditions.
3. The ability of an assembly to hold a given pressure with mud does not mean it will hold as much with water; the ability to hold with water does not necessarily tell anything about the gas pressure which will cause leakage.

In view of these statements, it seems obvious that the

FILL YOUR CASING AUTOMATICALLY

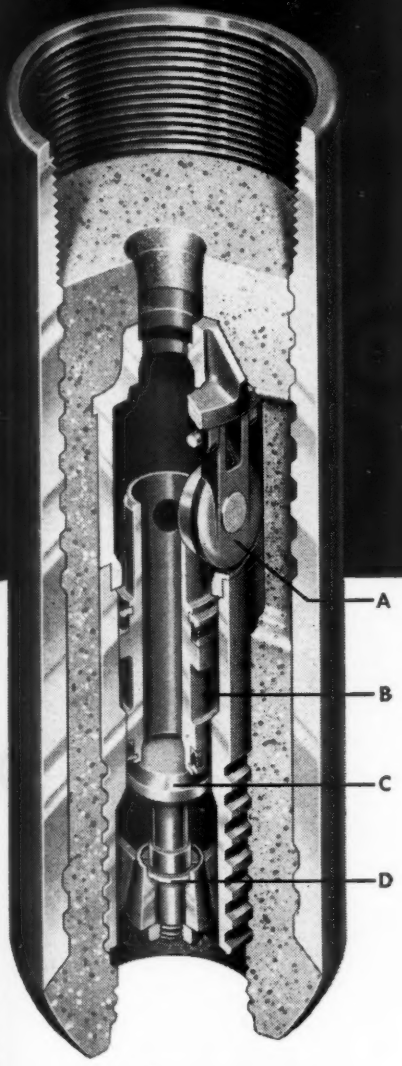
...from the bottom...while it's being run

with BAKER

• DIFFERENTIAL FILL-UP SHOES and
• DIFFERENTIAL FILL-UP COLLARS

Here's what DIFFERENTIAL FILL-UP Equipment does . . .

Permits the casing to *fill automatically from the bottom*, while it is being run, to within 90% of the fluid level of the annulus (using a shoe OR a collar)—or to within 81% of the fluid level of the annulus (using *both* a shoe AND a collar). In addition, a back-pressure valve is present to be used at the *discretion of the operator*, for "floating" or for cementing.



Baker DIFFERENTIAL FILL-UP Shoe, Product No. 1081.

A—Flapper Valve functions only at discretion of operator.
B—Sleeve Valve operates to control rate of flow and volume of "fill-up" fluid.
C—Sleeve Valve Seat.
D—Shear Ring is sheared. Flapper Valve now functions for floating or cementing.

Here's how Baker DIFFERENTIAL FILL-UP Equipment will aid you to avoid danger, increase rig efficiency, save valuable time and promote safety...

REDUCES THE DANGEROUS "RAM EFFECT" thus minimizing the hazard of breaking down a potential lost circulation zone.

SAVES COSTLY DRILLING MUD that might otherwise be lost to the formation due to the "ram effect."

MINIMIZES DAMAGE TO MUD CAKE on the wall of the hole. The majority of the fluid displaced as the casing string is lowered enters the casing instead of flowing up the annulus and causing possible damage to the mud cake.

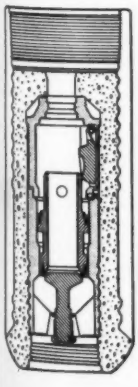
REDUCES DANGER OF STICKING CASING by reducing to a minimum the "no-motion time" formerly required to fill casing at the surface—extremely important when running casing in directional holes or sloughing formations.

SAVES ONE-HALF THE RUNNING-IN TIME plus the proven advantages of Baker Floating Equipment, including a back-pressure valve for cementing.

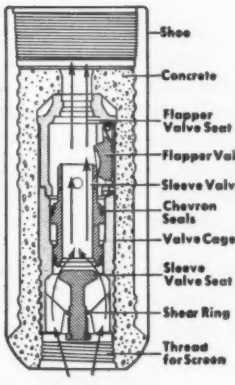
KEEPS THE RIG FLOOR CLEAN AND SAFE by eliminating the messy spill-over and splattering of mud present when casing is filled at the surface.

Ask any Baker representative or office for this new 16-page illustrated brochure . . .

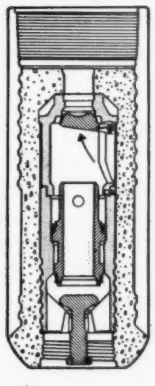
BAKER OIL TOOLS, INC., HOUSTON • LOS ANGELES • NEW YORK



When running-in, the Sleeve Valve is in closed position in contact with the Sleeve Valve Seat. When the Sleeve Valve is in this position, fluid entry into the casing from below the valve is effectively blocked. The Sleeve Valve will be in the closed position whenever the height of the fluid column in the casing (the fill) EXCEEDS 90% of the height of the fluid column in the annulus.



When the height of the fluid column in the casing (the fill) is LESS than 90% of the height of the fluid column in the annulus, the Sleeve Valve moves upward away from the Seat and permits fluid entry into the casing through the bottom of the FILL-UP Shoe. During the casing run, the Sleeve Valve opens and closes according to the pressures imposed on its top and bottom areas and thus automatically regulates the degree of fill.



When it is time for cementing, pressure of approximately 1,000 psi is built up in the casing to shear the Shear Ring that holds the Sleeve Valve Seat in the supporting vanes of the Valve Cage. The Sleeve Valve can then move downward sufficiently to release the spring-loaded Flapper Valve, and thereafter the FILL-UP Shoe functions as a conventional Float Shoe.

XUM

primary pressure control portion of an assembly should be pressure tested to some value carefully planned at least once a week. Although this practice is not general, its adoption could result in the saving of lives and property.

A simple way of making such a test would involve the purchase of a plug to seat and seal in a casing head when made up on the lower end of a stand of drill pipe. The sealing element of the upper blowout preventer would form the upper closure, and pressure could be applied in the annulus between the seals.

Secondary Control Equipment

The material described so far has fallen clearly under the definition given for primary equipment. Other equipment falls to some extent in that category, and to some extent in one which can be called secondary, and defined as all pressure control equipment which is not primary.

Considerable piping is required to transmit the flow of operating fluids from the sources of pressure to the operating portion of pressure operated valves and preventers. Valves are required to control the flow, and manufacturers of equipment ordinarily assemble suitable manifolds and panels which can be connected by conventional piping. All elements are, to some degree, general purpose equipment requiring nominal maintenance. Operation of the various primary units provides a periodic test of this equipment which is ordinarily adequate.

Pumps of one sort or another are the universal source of operating energy for the pressure operated primary equipment. There is extensive variation in the equipment used, and no detailed description is possible here, or particularly desirable.

Accumulators are sometimes used in operating manifolds as insurance against power or pump failure in an emergency. Most accumulators are simple pressure vessels arranged so that operating fluids can compress a volume of some gas to store enough energy to operate the equipment (Fig. 9).

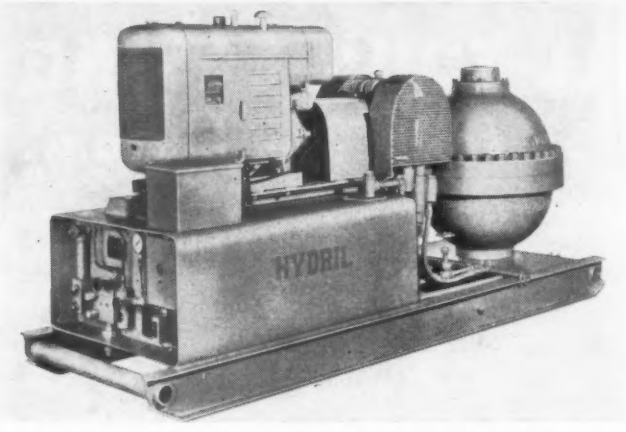
"Working" Type Well Bore Seals

Many units called "blowout preventers" and used rather extensively in many areas do not fit rigidly the definition for "Primary" equipment. They have one or more of the following functions:

1. They form a well bore seal during operations where external pressure is intentionally applied to the well and serve to prevent wear and damage to the primary, or emergency sealing elements. (This is a considerable service from the standpoint of both safety and economy.)
2. They form a well bore seal under conditions impossible or impractical for primary equipment. (Around a rotating kelly for example.)
3. They restrain low, initial development of formation pressures at the well head level until primary equipment can be brought into use.
4. When it is desirable to balance hydraulically only partially the formation pressures, as in drilling with water, oil, air or gas, they control the differential.
5. When reverse circulation is desirable, they form the closure which makes it possible to apply circulating pressure to the annulus.

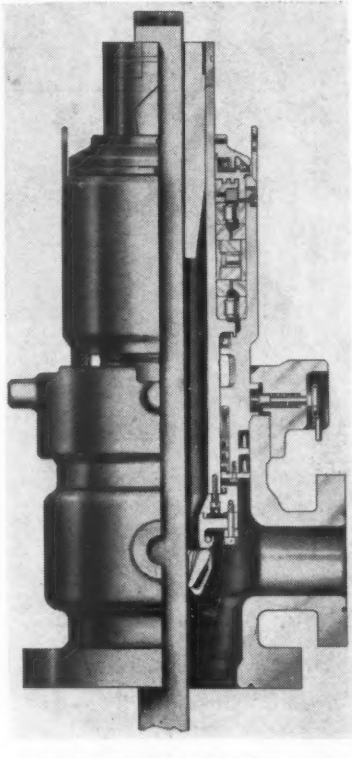
Rotating Packoffs

When drilling operations using light fluid or reverse circulation are carried on with conventional rotary tools for any sustained time it is necessary to use a closure for the annulus which rotates with the kelly or the drill pipe in order to reduce wear to a reasonable degree. Such pack-offs are ordinarily mounted in heads equipped with heavy sealed bearings which allow that portion of the head to which the pack-off is attached to rotate.



Hydril accumulator.

Guiberson drilling head.



Shaffer Type 50 combination rotating blowout preventer and stripper.

FIG. 9.

Shaffer Rotating Blowout Preventers

A quarter sectional view of the Shaffer rotating "blowout preventer" is shown in Fig. 9. The rotating portion of the unit is driven by a bushing at the top which fits the kelly. It is possible to pull or run the entire drillstring under pressure (with the exception of the bit) with this seal, although the drill collars produce a much higher rate of wear than does the drill pipe. It cannot pack off on an open hole, and it is ordinarily necessary to pull the bit above the master valve, close the master valve, and bleed off the pressure above it to remove the pack-off and the bit from a well.

Maintenance is relatively simple on this unit, and details will be supplied by the manufacturer upon request.

Guiberson Drilling Heads

Also shown in Fig. 9 is an illustration of the Guiberson "drilling head." Three types are currently manufactured

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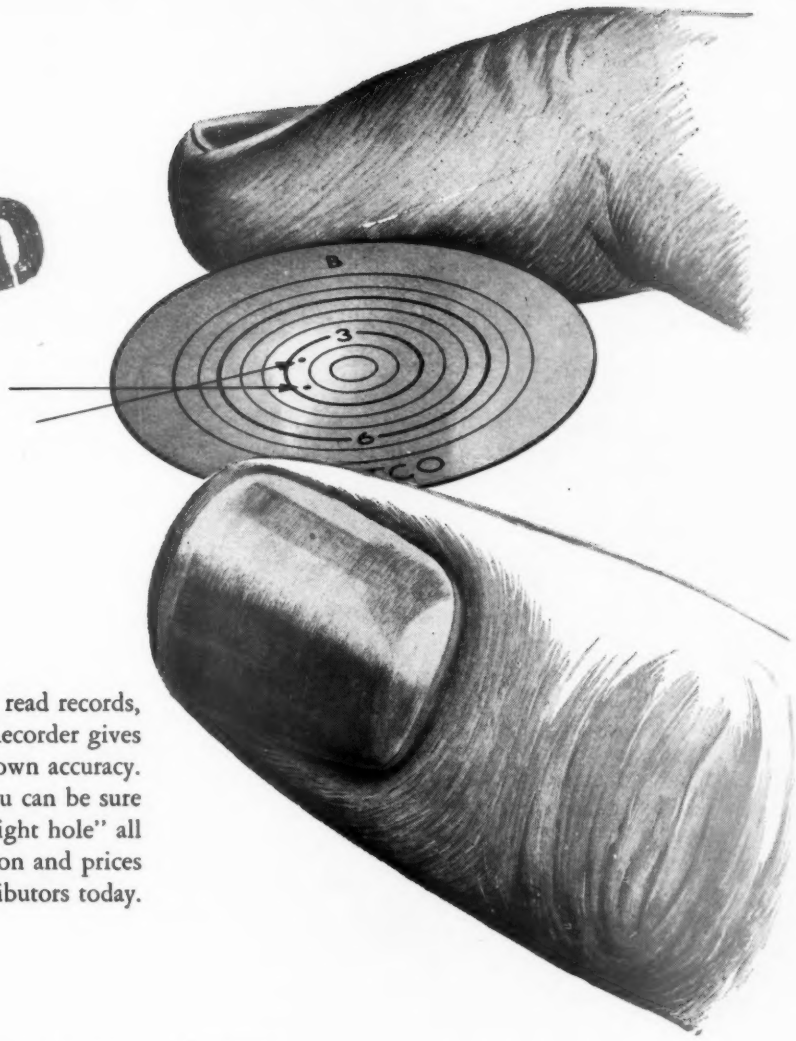

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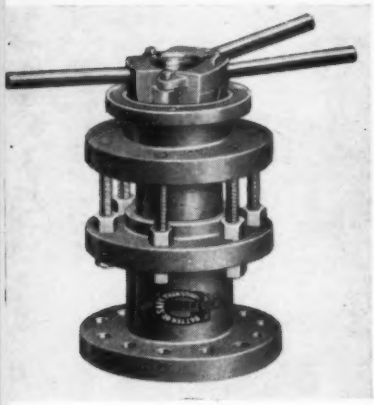
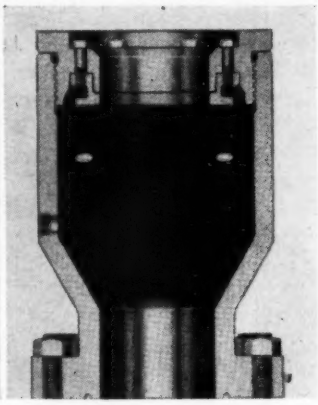
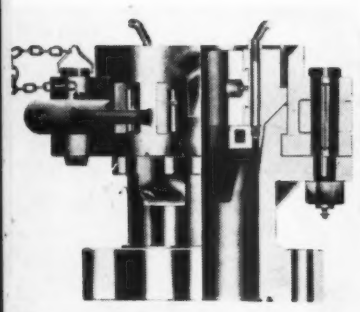


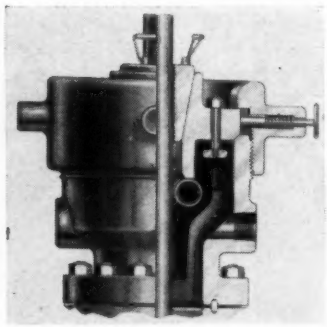
Guiberson.



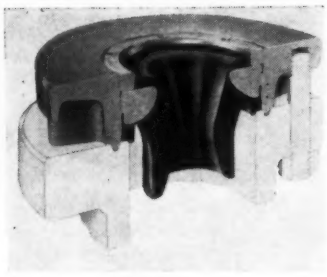
Hydril Type "RS."



Oil Center Tool Company.



Shaffer.



Petromec.

FIG. 10. STRIPPERS

with two differing primarily in detail, while the third type provides a drive mechanism and bushing by means of which pipe may be rotated without the use of a separate rotary table.

Other than for periodic lubrication and inspection, little maintenance is required.

While rotating pack-offs are relatively new types of equipment in their present form, comment from the users has mentioned only two improvements considered very pressing. These were increased ability to seal on a square kelly at very low pressures, and increased packing life on the sealing element.

Non-Rotating Pack-Offs

Use of the term "stripper" has been applied to the units that comprise this group of equipment by both users and manufacturers. This is unfortunate because the term implies a limit to the utility these units have. In general, they provide cheap, dependable packings or "stuffing boxes" through which pipe and tubing can be worked under pressure to accomplish many operations while saving time and materials. Fig. 10 illustrates several of these units which are in common use today. The OCT unit is simply the blowout preventer previously described except that the split packing element has been replaced with a "stripper" rubber which is expandible to accommodate and seal on a range of diameters. The Guiberson and Hydril units are somewhat similar except that they provide an arrangement for attaching a slip bowl at the top as a convenience in handling tubing, as also does the Shaffer. The Petromec unit is similar to these, except that it provides an upper surface upon which any make of tubing spider may be placed, and eliminates the flanged joint between the head and the next lower unit.

Among many operators, the practice of using a small tubing head with a stripper rubber installed to seal around tubing used as drill pipe in completion or recompletion operation is common. Such heads are often less expensive than some of the stripper heads, but are also sometimes less rugged. Some of these heads contain slip arrangements.

Automatic Casing Hangers

One type of equipment most usually classed as production equipment is frequently used to provide an annular seal similar to that afforded by the 'Hosmer' blowout preventer. These units are known generally as "automatic casing hangers." They are lowered through the pressure control assembly to seat in the well head upon which the assembly is mounted. Release of support on the casing by the elevators results in casing weight being transferred to the hanger and actuating the sealing mechanism of the hanger. When the assembly is removed, the annulus from the top of the cement to the well head has a mechanical closure as well as a hydraulic. Where its use is desirable, the threaded mandrel type hanger performs the same function.

Chokes, Choke Manifolds, and Fill-Up Connections

Under conditions where it becomes necessary for one reason or another to have a large pressure drop between the wellbore and the atmosphere on the returns, it is necessary to provide a choke manifold to regulate the rate of flow.

Such manifolds are a form of flow line which includes a flow line valve of some sort, a production choke, and the necessary piping to connect them and direct the returns as desired. It is common practice to employ dual manifolds so that the flow bean on one side may be replaced without shutting off the flow of returns.

In addition to regulating the rate of return flow, it is necessary sometimes to provide special connections, valves, or fittings to allow fluids to be put into the annular space between the pipe and the well bore. Ordinary fittings of appropriate pressure capacity and flow line valves are assembled in a number of different ways for this purpose.

General Remarks

Without exception, the equipment previously described is carefully designed, manufactured to high standards of quality, and thoroughly tested and inspected. Comments made are directed to beliefs widely held by users as to advantages and limitations inherent to *types* of design. Nothing said here is intended to imply that there is a difference in the quality of design or manufacture of similar or identical products since such comparison is entirely beyond the scope of this discussion.

All designs are compromises, and the designs discussed are no exception to the rule. No convertible does the work of a truck, and it's difficult to buy a Cadillac for the price of a Ford.

Rapidly increasing depths and pressures are accelerating the rate of improvement and refinement of designs in pressure control equipment. While the need for improved equipment is evident to all, it has not been generally understood that improvement in operating and maintenance techniques is even more important in meeting constantly increasing pressure control problems.

Lateral Drain Hole Drilling

Technique does not appear to have universal application. Excellent results in California grade to failures in other areas

H. JOHN EASTMAN

The first drain holes in wells in the West Texas area were drilled with the Lee Angular drill. Aside from those wells used by Lee in his experimental work during the development period, one well was laterally drilled at McCamey, two in the Slaughter Field, and one at Levelland during the period from 1944 to 1946. The McCamey well was completed in November, 1929, at a depth of 2032 feet. Initial production was 164 bbl oil per day. In June, 1934 the well was acidized with 1000 gallons after which it made 334 bbl. In early 1944 production had declined to a point where remedial work was required.

The San Andres lime reservoir consisted of a dense dolomite with very coarse limestone and varying quantities of anhydrite. It was decided to drill a lateral between 2009 and 2016 feet. This zone had a permeability of 83 per cent. A 25-ft hole was drilled with the Lee tool at the rate of 101 minutes per foot. Circulating fluid was 29 deg crude. The well was then acidized with 2500 gallons of acid solution and put on production. Production was increased 19 bbl per day by the combination of drain hole and acidizing. The producing company considered, however, that the additional oil yield was caused principally by the acidizing. The total cost of this workover was approximately $5100 including the acid treatment.

In January, 1945, four lateral holes were drilled in a San Andres lime well in the Slaughter field. The circulating fluid used was 33 deg crude. Holes were drilled between 5017 and 5021 feet, radiating from the main bore like the spokes of a wheel and spaced 2 feet apart vertically, at the rate of 100 minutes per foot to a length of 25 feet, 25 feet, 22 feet and 8 feet. Five thousand gallons of acid were used to treat the lime formation. In this well the least permeable portion of the pay zone was drilled and treated. No change in the production rate was noted. This workover operation cost about $7700 including the acid.

One well was drilled in the Slaughter field in 1945 to test the efficiency of drain holes in the least permeable section of the San Andres lime and was not acidized as was the normal completion practice in this field. A pump was installed and a production test indicated the settled production to be between 1½ and 3 bbl of oil per day. A permeability profile was run and the least permeable sections were chosen for drilling drain holes. Two sets of drain holes totaling 121 feet were drilled with 33 deg crude oil as a circulating medium. Three holes, 24, 22, and 3 feet long, were drilled at 4979 feet depth and four holes 24, 22, 18 and 3 feet long were drilled from 4928 feet depth. Penetration rate averaged from 50 to 95 minutes per foot dug. The pump was reinstalled and a production test made. The drilling of the drain holes increased the production to 13 bbl of oil per day. Later the lime was treated in two stages with total of 12,000 gallons of acid solution which increased production to 45 to 60 bbl per day. Several months later the settled production was 25 barrels.

The cost of drain hole drilling and acidizing was about $9800. Comparison with an offset well over a four months period in 1946 showed the well on which the experiment was run, had produced 58 per cent more oil than the well completed in a conventional manner.

In June, 1946, a series of five drain holes were drilled in the San Andres lime section of a well in the Levelland field. This well was located at the west edge of the proven field producing from a porous dolomite reservoir at 4825 foot depth. The lime zone selected for the drilling showed a porosity of 12 per cent and the residual oil saturation was 5 per cent. Two 25-ft upper laterals and three lower holes 25, 9, and 3 feet long were drilled with the Lee tools. The total time for this operation was 76 hours. Weight on the bit was increased from 1000 lb during the first three feet drilled, to a maximum of 5000 lb in the last 15 feet to overcome the drag of the tool in the curved hole. The bit was rotated at 50 to 60 rpm and oil was circulated at pump pressures from 300 to 500 lb. The drilling rate averaged 32 minutes per foot of hole dug. Before the laterals were dug, the average production was from 10 to 14 barrels. After the workover the settled production was 22 barrels of oil. After acidizing with 3000 and 7000 gallons of solution in two stages the yield was 135 bbl per day. This well was admitted to be the poorest in the field on account of its location on the structure, but it was felt that the drain holes had benefited it materially.

A number of wells producing from the Spraberry sand were completed or recompleted with drain holes in West Texas in 1951 and 1952. This reservoir is described as a siltstone of fine, hard, sand of quite variable oil content about

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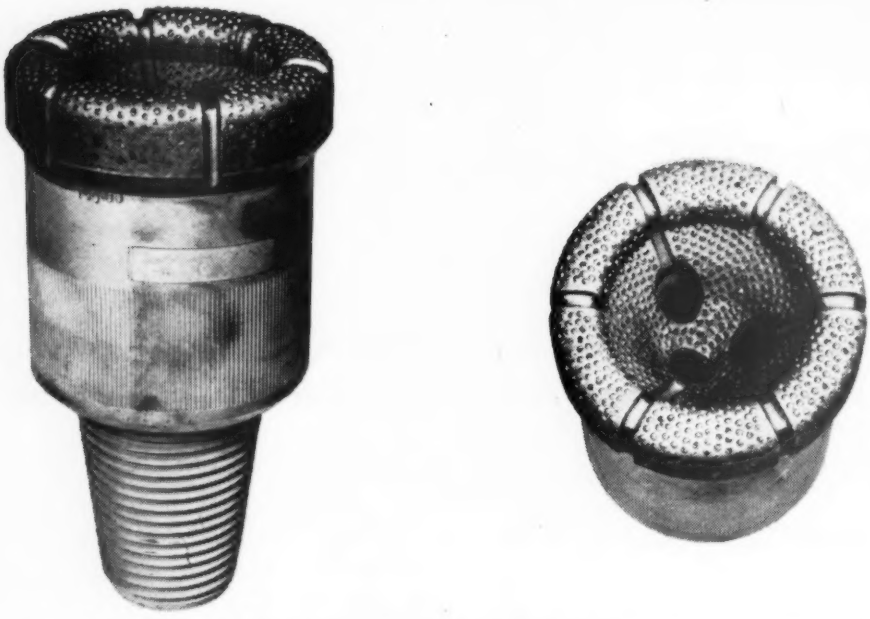

One type of diamond bit used for drilling drain holes in hard formation. Left photo shows side of bit and right photo is bottom of bit showing cutting diamonds and circulating holes.

1000 feet thick. About 100 to 150 feet of what is called the Upper and Lower Spraberry is most productive. The oil appears to be associated with vertical fractures which lie in a pattern trending about N 75° E and a number of techniques were used to assist production. Many wells which came in as good producers declined so rapidly that they were not financially successful. Acidizing, shooting, and hydraulic fracturing were tried, often in conjunction with laterals drilled into the Spraberry section, in attempts to penetrate more fractures and produce more oil.

Results from drain hole drilling of the Spraberry zone were either inconclusive or showed little or no improvement over other accepted completion techniques. Most of the completions were made in conjunction with fracturing or shooting and possible benefits thereby masked.

An interesting directional drilling job done in November 1951, however, is related to the purpose for which lateral drilling was intended and worthy of reporting.

The idea of this operation was to deviate a high angled hole through the Spraberry formation perpendicular to the fracture trend to intersect as many vertical fractures as possible. It was hoped that the opening of a large number of fractures would improve the well's capacity to produce. The well was whipstocked at 4910 feet depth and angle increased at a rate of 2½ deg per hundred feet drilled. The maximum angle of 58 deg was reached at the top of the pay sand and the angle averaged 55½ degrees through the pay section. Due to this angle in the hole the well traveled 127 feet horizontally in the productive formation.

Coring indicated that several fractures were cut trending from due east to northeast. Casing was set and perforated at bottom. The well was swabbed dry and given a wash acid treatment after which it again was swabbed and given a fracture treatment with 3000 gallons of gel.

The well swabbed 3 barrels of fluid per hour and was placed on the pump. It was completed in mid-April, 1952, and produced top allowable for some time. It seemed to be a better than average producer and did not decline rapidly.

Comparison with a direct 40 acre north offset drilled a year before the deviated well shows an average of 20 bbl per day greater production since it was completed. Admittedly, neither well is very good; the area has proven to be a very poor one.

New Mexico

Two gas wells in north western New Mexico were drain hole drilled as an experiment. One in the Farmington area had three short drain holes drilled in the Cliff House formation. Drilling was done with natural gas under pressure instead of mud as a circulating fluid. A twenty foot lateral was drilled at the rate of 2½ feet per hour at 3970 feet. A second lateral, five feet higher up the hole, was drilled out 31 feet. The third drain hole was 22 feet in length.

The operator reported that the lateral drilling had little or no effect on the gas production from the well.

In September, 1952, two 50-ft drain holes were drilled in the completion of a gas well at Largo Canyon, New Mexico, at a depth of 2185 feet in the Pictured Cliffs sandstone.

Before commencing the drain holes the well gaged 734 MCF of gas natural. After drilling the holes the volume of gas had increased to 1140 MCF. The main bore of the well was shot with 300 quarts of nitrogel. After completion the well then gaged 5723 MCF. Based on experience in drilling 27 wells in the same area, it was the opinion that the two lateral holes increased the capacity of the well by about two million cubic feet of gas per day. No further drilling of this kind was attempted since time consumed and cost involved did not warrant drilling drain holes as a standard completion practice.

North Louisiana

During 1942 and 1943 a major producing company drilled drain holes in 6 wells on one lease at Pine Island, Louisiana. This reservoir, which lay at a depth of 1500 feet to 1700 feet, was a very fine, tight, chalk formation which had proved very difficult to produce. It was soft and drilled easily but was very impermeable. Although tests had shown that the Annona chalk held about 100,000 barrels of oil per acre, it was estimated that only about 7 to 10 per cent could be recovered by conventional methods.

The original completion of the wells was made in 1936. All of them were acidized as a standard practice. Production of all wells had declined by 1942 to a point where they required a workover. Five wells were recompleted with 8 drain holes each while sixteen holes 23 feet long were drilled in one well. Drilling was done by production crews using 37 deg oil first as a circulating fluid. Since poor cutting returns were obtained 17 deg crude was used on almost all the operations. The formation was relatively easy to dig; the penetration rate was 10 to 15 minutes per foot. All laterals radiated from the main bore like the spokes of a wheel. Generally they were 90 deg apart in direction of 2 sets of 4 holes each. Each set was at a different depth in the well. Average length was 20 ft.

A settled production test was made on each well after the drain holes were completed both before and after gas-acid treatment. Appreciable increases were shown but the greater benefit was gained after acid treatment. Undoubtedly the drain holes made the use of acid on lime forma-

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tion more effective since the acid was able to penetrate more widely in the reservoir on account of the laterals. It was felt, however, that the 17 gravity crude used as circulating fluid in drilling the drain holes had adversely affected the formation, partially defeating the effectiveness of the gas acid treatment. All lateral holes were drilled from 1500 to 1700 foot depth and in each case 8000 gallons of solution was used in the gas-acid treatment.

Evaluation of the benefits of drilling drain holes in limestone formations is difficult to make from the work done on these wells. All wells were eventually acidized, no liners were used, holes were of limited length, so no definite conclusions can be drawn.

Wyoming

Lateral drain holes were drilled in five old wells owned by one operating company in the Oregon Basin, Lake Creek, and Kirby Creek fields in Wyoming. Well "A" was deepened to produce from the Tensleep sand at a depth of 3633 feet in the Lake Creek field. Recompleted in July, 1950, three drain holes were drilled in the pay zone between 3595 and 3606. The reservoir sand was quite hard and only 23 feet of hole was out in the three laterals.

A nearby producer had been completed without drain holes in the same reservoir about three months before this well. Although structurally higher it has not been quite as productive as Well "A." Averaging the last nine months of production from both wells (adjusted for the three months difference in the completion dates) Well "A" has produced 123 bbl per day and the offset has produced 117 bbl per day. Possibly this difference is caused by the laterals drilled in Well "A." The laterals cannot be considered as efficient in draining the reservoir as longer holes might have been.

Well "B" was drilled in early 1948 at Kirby Creek. It had averaged about 35 bbl per day until May, 1952, when it was decided to drill three drain holes in an attempt to increase production. Nineteen feet of laterals (holes were 10 feet, 4 feet and 5½ feet long) were drilled with a diamond tipped bit. The oil used in drilling was being lost to the sand so fragments of cellophane foil were mixed with the circulating oil to prevent loss. This material balled up on the diamond bit preventing it from cutting effectively so the last two short holes were drilled without circulation. Production decreased after this operation from 30 bbl per day (44 day average previous to the workover) to 14 bbl per day. This decrease was attributed to the plugging of the pay section with cellophane and the fine cuttings made by the diamond bit. It was reasoned that since there was not enough reservoir pressure to expel this material from the producing zone that it had been mechanically plugged. The last report was that some sort of solvent would be used to dissolve this material.

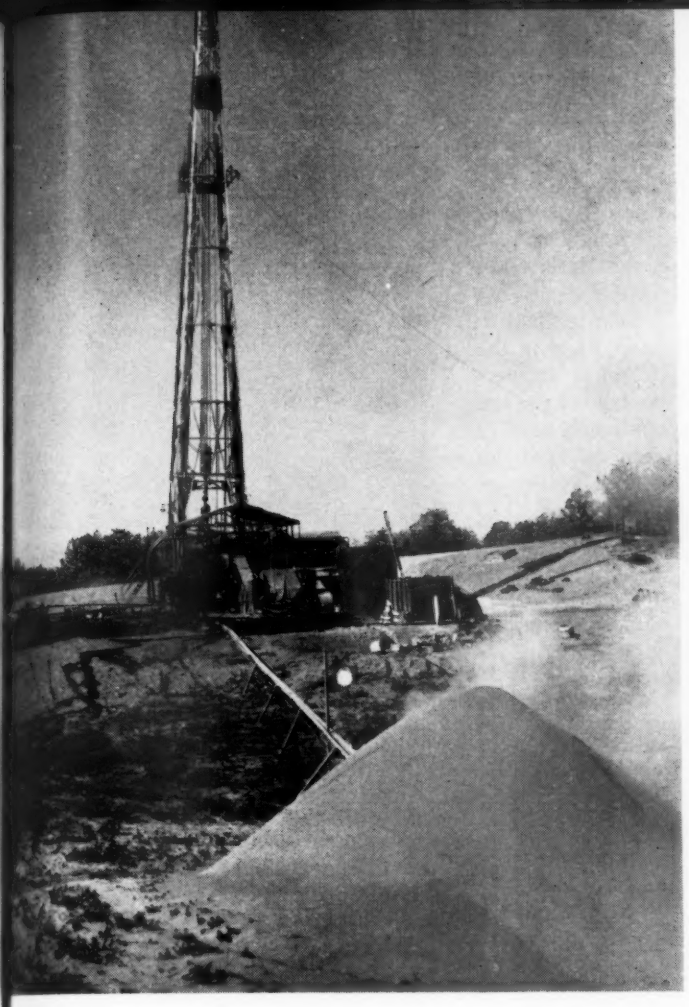
Well "C" was completed in the Kirby Creek field in July, 1947. Before it was worked over in May, 1952, the well was pumped once a week for an average daily production of 1.56 barrels of oil. Two drain holes, one 24 feet and the other 75 feet long, were drilled in the producing zone at 3416 and 3450 feet depth without beneficial effect.

In May, 1952, three short drain holes were drilled in the producing section of Well "D" which had just been deepened to produce from the Tensleep sand in the Oregon Basin field. Drain holes 8, 19, and 7 feet long were drilled from depths of 3643 to 3660 in the Tensleep formation. No well in the field drilled to this same sand exists which can be used as a true comparison to determine whether the drilling of drainholes in Well "D" was successful from a standpoint of oil produced.

Well "E" was located in the Kirby Creek field and was originally put on production in May, 1948. Two drain holes were drilled in this well, one 21 feet and the other 70 feet long. This well produced 13.22 barrels of oil per day for the last 35 days preceding the work over. After the 720 barrels of oil used in drilling the drain holes was recovered the average production was ten barrels. During the drilling there was a constant loss of oil to the formation and it was concluded that the fine cuttings made by the diamond bit had plugged the oil sand. The formation was unable to expel these cuttings since the formation pressure was too low for it to do so.

A well completed in the Muddy Sand in the Borie Field near Cheyenne was drilled with laterals in June, 1952. The reservoir consists of a very tight sand highly fractured vertically. Daily production averaged 65 bbl per day before the workover operation began.

Previous to the drilling of drain holes the oil sand had been hydraulically fractured in an unsuccessful attempt to increase production. Two holes, one 19 feet and the other 39 feet long, were drilled at 8525 feet depth. Production records on this well do not show any benefit gained from drilling these short laterals. It is possible that the rate of decline was less after the holes were drilled. This lateral drilling was done, however, as a last resort since all other aids to increased production had failed. * * *



Bit on right drilled 723 ft using compressed exhaust. Left bit cut 14 ft using mud in roughly comparable formation.

Cuttings pile up at end of vent line in vapor drilling experiment.

Successes with air and gas led to

Exhaust Drilling in Arkansas

Fire and explosion hazards are reduced, drilling penetration speeded in this unique experiment

SIM H. CREWS*

FORMATIONS below 3600 ft in the Morrilton area of Arkansas, about 100 miles east of Fort Smith, are almost ideal for rotary drilling with gas as the circulating medium. At that depth, the hard and unusually dense strata is dry and operations are not complicated by ground waters.

Realizing this, yet seeking to avoid the increased fire and explosion hazards resulting from drilling with natural gas or compressed air, Carter Oil Company management conceived and implemented a plan whereby the inert exhaust gases from the drilling engines and the engine driven compressors could be utilized as a circulating medium.

Calculations indicated that, from the drilling engines and the three compressor engines which experience dictated would be required, a total of 2600 cu ft of exhaust gas per minute would be available. It was realized that this gas would have at least two undesirable characteristics. It would be too hot for compression and it would contain corrosive elements that would adversely affect the compressing equipment and the drill pipe. With these deficiencies corrected, however, it would provide an economical and, more important, a non-explosive and fire-safe gas readily available in sufficient quantities for drilling operation.

Carter had surplus atmospheric heat exchanger bundles available from one of its gasoline plants. Using two of these bundles and shell and tube coolers from the surplus stock, exhaust gases were cooled to 90 F. This cooling condensed a part of the water vapor, one of the combustion products, in the exhaust and permitted its extraction by separators. Treatment then with

*Editor, Drilling and Producing edition.

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corrosion inhibitors completed preparation of the gas for compression.

Three rotary compressors were used for building gas pressure up to 100 psi for drilling use. These compressors were capable of delivering 1500 cu ft a minute at 100 psi.

Results of this operational experiment were exceptionally good. Prior to setting protective casing string at 3600 ft, progress in drilling Carter's No. 1 J. H. Jones had been slow and expensive. Using 9.6 to 10.4-lb mud as a drilling fluid, the interval from 3102 to 3609 ft had required 20 rock bits. One bit below 3100 ft required 20 hr to drill 23 ft of hole. The next one made the first foot in 3¼ hr. Average drilling rate just above 3500 ft was 25 ft per day.

Carter had first drilled a 9-in. hole in the interval from 3102 to 3345 ft. This 243 ft of hole required 8 rock bits. Average penetration rate was 2.94 ft per hr and average bit penetration was just over 30 ft per bit.

This 9-in. hole was then reamed to 13¾ in. and drilling continued in the big hole to 3609 ft with mud. Bit performance in the larger hole was even less satisfactory, 12 bits being used in the 264 ft. In this interval, average penetration was only 22 ft per bit at an average rate of 1.94 ft per hr.

Burning flare will safely ignite production from any oil or gas zone drilled.

After cementing the protective string, the hole was evacuated and drilling with compressed exhaust gases started. The first bit out from under casing made 148 ft in 13 hrs. The next one drilled 175 ft in less than 12 hr. Continuing the experiment then, Carter management decided to make an unusually long bit run and left the third bit under the protective string in the hole 58 hr. This record run produced 723 ft of hole at a penetration rate of 12.48 ft per hr, probably both a rate and a total not previously equaled in this part of Arkansas. And, more interesting than its performance, if possible, was the excellent condition of the bit cones when pulled, as evidenced in the photograph on page B-115.

Exhaust drilling was used to total depth with continuing excellent results.

The 1529 ft interval from 3607 to 5138 ft required only 4 rock bits, penetration per bit averaging 382 ft. Penetration rates averaged 11.2 ft per hr, over six times as great as those achieved above 3609 ft with 13¾-in. bits and nearly four times those delivered by the 9-in. bits above 3345 ft.

As outstanding as the penetration rate records are, however, possibly of more significance is the total bit performance. On the average, one bit, operated with gas did the work that 13 used with conventional mud had delivered at shallower depth in this Carter wildcat.

Carter Oil has thus added an important bit to the sum of knowledge accumulating in the drive to lower drilling cost. The inherent safety of drilling with an inert gas with attendant low fire hazard, the greater bit penetration, and the higher penetration rate all offer attractive possibilities for exploration to both operators and drilling contractors.

Credit — Based on article published in *The Link* publication of The Carter Oil Company.

* * *

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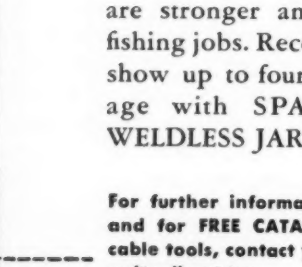

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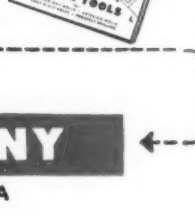

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At 15 Colleges

Stanolind Foundation Awards Fellowships To 16 Students

Sixteen graduate students in seven different fields of study received Stanolind foundation fellowships to 15 different colleges and universities for the 1954-55 academic year.

Robert S. Newhouse, director of industrial and public relations for Stanolind, reported that each of the 16 fellows was awarded a stipend of $1500 plus tuition and fees at each school. Stanolind Foundation, Inc., was created and is supported by Stanolind Oil and Gas Company. Newhouse explained that the fellowship program was started in 1937 with one fellowship to the University of Texas.

School Selects Fellows

Graduate studies included in the fellowships are petroleum engineering, geology, chemical engineering, chemistry, geophysics, accounting, and mechanical engineering. Fellows are selected by college and university officials, and the fellow studies any phase of the course he wishes.

Following is a list of fellows with the college or university each attends and the subject he is studying:

Arthur Roy Price, chemical engineering, Rice Institute; Robert Alwyn Bowers, geophysics, University of California; William H. Scott, petroleum engineering, University of Tulsa; William E. Portman, petroleum engineering, University of Oklahoma; Richard E. Wainerdi, petroleum engineering, Pennsylvania State University.

Rolfe S. Stanley, geology, Yale University; George K. Sirrine, geology, University of Texas; Prentiss D. Lewis, geology, Louisiana State University; John Ed Hansford, mechanical engineering, Oklahoma A and M College; Marcus Gerhardt Langseth, Jr., geology, Columbia University.

Richard E. Kucera, geology, University of Colorado; Kenneth A. Pollart, chemistry, Kansas State College; Robert N. Clayton, geo-chemistry, California Institute of Technology.

George J. Heuer, Jr., petroleum engineering, University of Texas; Stewart Voorhies Veale, accounting, University of Pennsylvania, and Denton R. Wieland, petroleum engineering, Texas A and M College.

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EXPLORATION ACTIVITIES

KANSAS

★ The Texas Company has opened a new oil pool in Kansas with the completion of the No. 1 Urbanek as a producer in Ellsworth County.

The Arbuckle lime from 3410 ft to 3431 ft was completed through perforations 3413 to 3418 ft and the well swabbed 73 barrels of oil, no water, in one hour. The discovery well is located one mile east of the Stoltenberg Pool.

ARIZONA

★ Colorado Basin Associates has spudded the first of a series of 3 wildcats scheduled to be drilled on a mesa south of Yuma, Arizona. Fowler Drilling Company of California brought in a rig from Bakersfield and is doing the drilling. The initial test is on the SW¼ of the NW¼ of Sec. 19, T-9-S, R-23-W. The tentative site of the second test will be about 1½ miles to the north.

COSTA RICA

★ The initial test on the large concessions held by Union Oil Company in Costa Rica, Patino 1, spudded in the latter part of November and is currently drilling ahead. The well is projected to a depth of approximately 7000 ft.

TEXAS

★ A new pay for the Dora Roberts Ranch pool of Midland County was reported by Cities Service and Forest Oil Corporation when their Dora Roberts B-1 No. 2 flowed oil at the daily rate of 720 bbl during a drillstem test in the Pennsylvanian sand from 10,104 to 10,263 ft. Other production from this prolific area has been from the Ellenburger sand and the new well is the first from the Pennsylvanian on the north side of the ranch.

★ A 19,441 acre block of the Lincoln Ranch, section 1313, S & M Survey No. 1724, Webb County has been acquired by Sunray Oil Corporation. Sunray will drill a 7200 ft Wilcox sand test to seek the productive zones found in the Hirsh and Nicholson fields. The land is some 40 miles west of the town of Freer, and the lease was taken as a result of recent seismic surveys conducted by Sunray on vast areas of the South Texas acreage.

★ British-American Oil Producing Company's J. B. Tubb No. 1 wildcat, located 14 miles south of Monahans in East Central Ward County, Texas, in the center of SW NW Section 13, Block B-20 PSL, encountered flowing oil on a drillstem test in the Ellenburger lime from 8226-8290 ft. The test tool was open 158 minutes with gas coming to the surface in 3 minutes and 47.1 gravity oil flowing in 9 minutes at the rate of 93 bbl per hr. No water was recovered when the oil was reversed out of the drill pipe.

The J. B. Tubb No. 1, which is 3 miles north of the West Sand Hills field, also tested strong gas flow on several drillstem tests in the top part of the Ellenburger section between 8048 and 8226 ft. Flowing oil on drillstem test was obtained previously in the Glorietta pay zone from 3979 to 4080 ft and the Wadell zone from 7699 to 7755 ft. Other zones having production possibilities in this well are the San Andres at approximately 3470 ft and the Fusselman at approximately 6300 ft.

★ D. D. Feldman Oil and Gas, Dallas independent producer, has announced the completion of a DeWitt County discovery as a gas-distillate well.

The well is the firm's Naomi W. Gohlke in the John T. Tinsley survey, A-445, and is located approximately three miles southeast of Yorktown.

Drilled to a total depth of 7707, it was rated, on an open flow potential, at 15,000,000 cu ft of gas per day with 24.6 barrels of 70-gravity condensate per 1,000,000 cu ft. Production is from perforations from 7324 to 7325 ft in the Upper Wilcox sand. On a 14/64-in. choke, the well produced at a rate of 2,937,000 cu ft of gas per day with a tubing pressure of 3175 lb.

★ Texaco also announced the completion of the No. 1 J. F. Welder Heirs well 7 miles east of San Patricio, San Patricio County in south Texas, as a gas well. Completed through perforations 7616 to 7628 ft, in the lower Frio sand, the wildcat flowed at the daily rate of 4.65 million cu ft of gas on a quarter-in. choke. Tubing pressure was 3150 lb and shut-in pressure, 3500 lb. The well originally was drilled to 8748 ft, then plugged back. It is located a mile west of the Odem pool.

Summary of drilling activity for November.
(As compiled by Rinehart Oil News Staff)

States	New locations		Wildcat completions			Field completions			Junked & abnd.		Temp. abnd.		Abandoned locations		Current active wells	
	Wc	Field	Oil	Gas	Dry	Oil	Gas	Dry	Wc	Field	Wc	Field	Wc	Field	Wc	Field
Alabama	3	1	0	0	3	0	0	1	0	0	1	0	2	1	6	1
Arizona	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Akransas	11	41	2	0	7	21	0	11	0	0	0	0	0	1	15	16
Canada (Williston B.)	29	56	3	0	16	29	0	3	0	1	0	0	0	13	21	18
Colorado	73	46	3	1	62	36	4	20	0	0	0	0	2	0	54	48
Florida	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0
Georgia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idaho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Kansas	104	347	17	7	52	195	31	107	0	0	0	0	2	4	82	344
Louisiana	58	321	3	5	40	176	46	51	3	3	0	4	1	8	68	247
North	26	161	0	0	21	86	13	35	0	0	0	0	1	1	20	37
South	32	160	3	5	19	90	33	16	3	3	0	4	0	7	48	210
Mississippi	18	29	1	0	9	11	1	14	1	0	0	0	0	0	17	33
Montana	7	28	0	2	6	19	1	1	0	0	0	1	2	3	23	32
East	1	10	0	0	1	8	0	0	0	0	0	1	2	1	5	11
West	6	18	0	2	5	11	1	1	0	0	0	0	0	2	18	21
North Dakota	6	8	0	0	8	10	0	0	0	0	0	1	0	0	6	19
Nebraska	26	33	5	0	15	7	0	11	0	0	0	1	0	0	11	30
Nevada	0	0	0	0	2	0	0	0	0	0	0	0	0	0	4	0
New Mexico	21	90	2	4	9	46	31	6	0	0	3	2	3	1	40	124
Eastern	13	60	2	1	5	46	4	5	0	0	3	1	3	1	31	81
San Juan	8	30	0	3	4	0	27	1	0	0	0	1	0	0	9	43
Oklahoma	81	574	8	3	58	378	25	146	1	2	0	2	0	27	52	424
South Dakota	1	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0
Texas	559	1460	73	16	375	829	91	237	0	3	12	16	10	49	451	924
East	49	71	2	1	34	30	22	14	0	0	0	0	0	2	28	104
Gulf Coast	49	122	3	1	30	62	6	28	0	2	0	2	2	1	41	76
North Texas	116	322	20	0	64	186	6	72	0	0	0	3	0	4	76	99
Panhandle	8	72	2	0	2	29	17	2	0	0	0	0	0	0	24	26*
South Texas	117	270	3	8	103	127	28	37	0	0	9	9	1	4	70	95
Border Co.	29	73	9	0	24	52	1	8	0	0	0	0	0	4	28	73
West Central	121	189	22	2	85	122	2	59	0	1	1	0	7	21	51	67
West Texas	70	341	12	4	33	221	9	17	0	0	2	2	0	13	133	384
Utah	8	0	1	0	5	0	0	1	0	0	0	0	0	0	33	4
Wyoming	18	45	5	1	25	41	0	8	0	0	0	0	1	1	51	72
Totals: Jan	699	2425	121	47	611	1780	254	584	6	5	10	21	17	144	808	2359
Feb.	713	2816	101	28	503	1583	228	542	0	5	21	22	29	98	845	2362
Mar.	975	2945	115	42	585	1866	242	605	0	6	27	33	16	69	950	2659
April	966	3166	117	46	665	2006	186	618	2	4	20	24	25	108	953	2665
May	879	2727	92	35	600	1762	170	478	2	2	29	21	13	92	945	2580
June	1074	2978	110	42	704	1759	250	524	4	2	36	59	35	113	1008	2640
July	1018	2940	132	42	727	2059	255	666	1	4	15	40	14	117	936	2361
Aug.	887	2880	111	38	734	1848	226	616	5	5	17	20	31	83	872	2349
Sept	916	2940	107	38	715	1907	232	608	10	8	23	40	27	82	902	2406
Oct.	960	2918	114	22	634	1753	195	601	5	7	19	30	23	81	891	2249
Nov	1024	3080	123	39	695	1798	230	617	5	9	16	27	24	108	940	2336
1954 Total	10,111	31,815	1243	419	7173	20,121	2468	6459	40	57	233	337	254	1095	—	—

* Figure incomplete.

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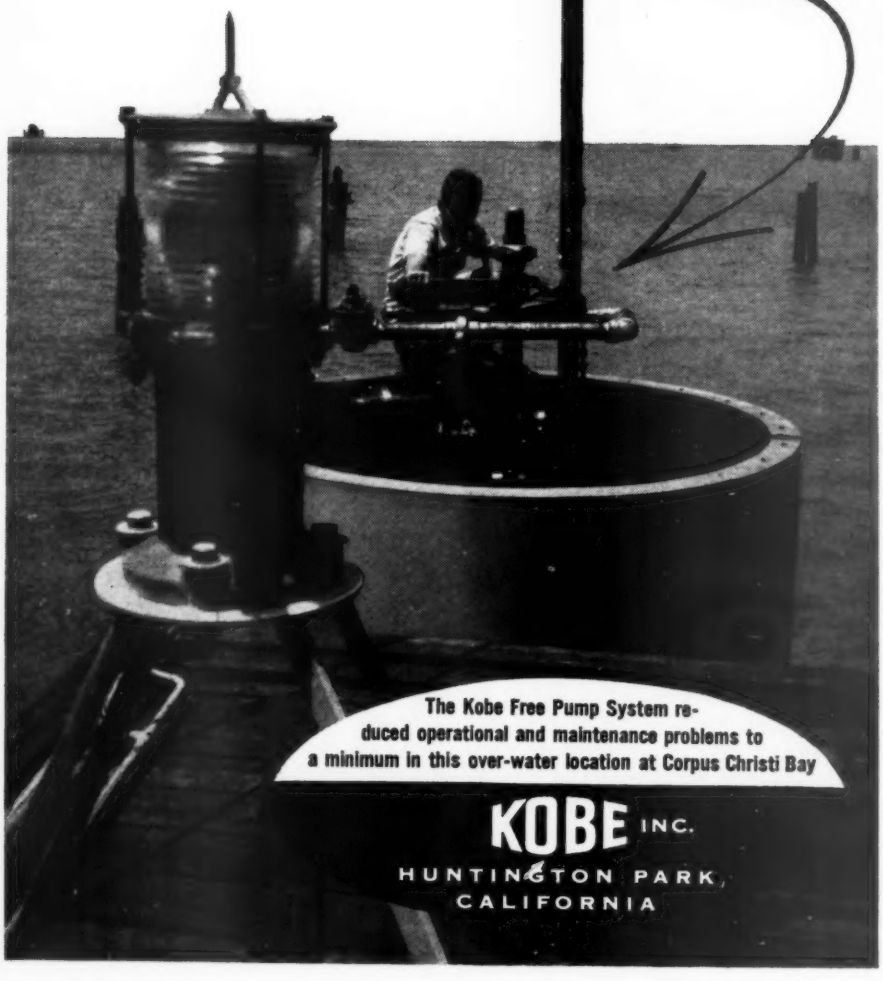

The Kobe Free Pump System reduced operational and maintenance problems to a minimum in this over-water location at Corpus Christi Bay

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Exploration

OKLAHOMA

★ Logan County has been the scene of a new and large gas producer. The Powell Brisco No. 1 Poteet was tested at an estimated 30,000,000 cu ft per day in a natural completion from the Layton sand. Completion was through casing perforations 4586-96 in the opener which is situated about 2 miles southeast of the East Guthrie Lake field.

★ Stanolind Oil and Gas has an apparently important Bromide sand discovery in Garvin County in its Pitchlynn No. 1. On a drillstem test of the sand in the section 5844 to 5981 ft, the well flowed oil after the tool had been open about 30 minutes and continued to flow at the rate of 12 bbl per hr. The location is near Maysville in the southern part of the state.

LOUISIANA

★ Discovery of additional important gas-condensate sand in a southwest extension of the Lake Arthur (South) field of Jefferson Davis Parish, Louisiana, has been confirmed by the Union Sulphur and Oil Corporation of Houston, Texas.

The well is Union's Maple Hughes B-1 which was drilled to a total depth of 13,473 ft. The new deep sand zones were topped at 12,315 ft and bottomed at 12,705 ft with 188 ft of net gas condensate pay in this interval. Drillstem tests of these sands recovered gas with flowing pressures in excess of 6000 psi and bottom hole pressures of approximately 10,000 psi.

★ Cities Service announced the site of a test well, the Granger No. 1, as being 9 miles east of New Iberia, Louisiana, and 1¼ miles southwest of nearest production in Fausse Point. Principal objectives are the Miocene sandstones with an expected total depth of 10,500 ft.

★ Cities Service announced the completion of a Miocene discovery in Assumption Parish, for a calculated open flow of 110 million cu ft of gas daily. Condensate from the new well, the Brownell-Kidd B No. 1, has been gaged at 40 bbl per million cu ft of gas. Flowing tubing pressure was 4372 lb with a one hour shut-in pressure of 4646 pounds.

In the completion test following perforations opposite the Miocene at 13,550-72, the well flowed at the rate of 5.4 million cu ft per day with 221.6 barrels of condensate. The test was made through a 15/64-inch choke.

Total depth of the well is 14,302 ft, plugged back to 13,599 ft. Packer was set at 13,540 ft. The discovery is appromixately 4 miles west of nearest production in the Napoleonville pool and is 28 miles south of Baton Rouge.

CANADA

★ The Sunray-Pacific Petroleums-Montney No. 2, LSD 14, 36-86-19 west 6th meridian, Province of British Columbia, Canada, has encountered showings of natural gas in both the Cretaceous and Triassic zones equivalent to approximately 7,000,000 cu ft per day along with a quantity of condensate.

The Canadian well, being jointly drilled by Sunray Oil Company, the Canadian subsidiary of Sunray Oil Corporation, Tulsa, and Pacific Petroleums Ltd., Calgary, Alberta, Canada, is testing a 150,000-acre block lying south and east of the 2 companies' recently successful Buick Creek discoveries. The wildcat is the first of 2 wells the companies will drill to the Permo-Pennsylvanian at 6300 ft. The first showing of gas was at 416 to 36 ft, and drillstem tests at intervals of 4200 to 4300 ft indicate gas-bearing zones through several hundred feet of pay section.

CALIFORNIA

★ Tide Water Associated Oil Company announced that it has completed its Lloyd No. 167 D-8 well in the Ventura Avenue field which came in flowing 1107 bbl per day of 33 gravity oil and 932,000 cu ft of gas through a 14/64-inch choke. Total depth was 12,900 ft and constitutes about a 1-mile easterly extension of the D-8 zone yet found in the Ventura Avenue zone, which is the deepest producing field.

★ Reserve Oil and Gas Company has reported the completion of Reserve-Pauley 48-27, which is the seventh well to be completed by the company in the Olcese pool, a new zone discovery made early this year in the Tejon Ranch field in Kern County. The well produced 30 gravity oil at the rate of 710 bbl per day on a 5-hr test.

★ Trico Oil and Gas Company announced completion of its first development well on its recently purchased Moffat gas field in Madera County. The well, Moffat 1-6, was completed at a total depth of 3966 ft and flowed 11,000,000 cu ft of gas through two-inch tubing holding 1590 lb pressure.

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WHAT'S DOING IN DRILLING

TEXAS

★ Biggest oil well in the South Cowden-Ellenburger pool of Ector County has been reported by Cities Service in the completion of the jointly owned TXL "N" No. 1 for a flowing potential of 2165 barrels of oil daily. At a total depth of 12,970 ft in the Ellenburger dolomite, the well flowed 451 barrels of oil in five hours through a ¾-in. choke. Flowing tubing pressure was 450 lb and the gas-oil ratio was 797 to 1.

★ Completion of a new well in the Mulder Oil Creek field in Grayson County, Texas, has been announced by D. D. Feldman Oil and Gas, Dallas independent producer.

The well, Bailey-Mulder No. 1, is in the James Coryell survey, approximately four miles northeast of Sadler. Drilled to a total depth of 8,310 ft, casing was perforated from 7676-82 ft at four shots per foot, and from 7732-38 feet at six shots per foot. The latter zone is scheduled to be produced, although production was found at both zones in the Mulder Oil Creek formation.

The well's initial production on a potential test was at the rate of 169.44 bbl per day of 42.8 gravity, corrected, on a 10/64-in. choke with 600 pounds tubing pressure. The gas-oil ratio was 892 to 1. Contractor on the well was Howell, Holloway and Howell.

CALIFORNIA

★ Basin Oil Company completed Inglewood Community No. 1-2 for 165 bbl per day 29 degree gravity crude and 1,000,000 cf of gas. The well was drilled to 8664 ft and plugged back with 7-in. casing set to 8439.

★ Kalpure Oil Company completed Kalpure No. 1 in the Edison field in Kern County. The well was completed flowing 576 bbl per day of crude from an interval at 4603-4681 ft in the Nozu sand. Des Moines Oil Company has staked location for a westerly offset to Kalpure's well, to be known as Cauley No. 10, on Sec. 16, 30-29.

★ Richfield Oil Corporation completed Gordon No. 343 in the Wheeler Ridge field. The well was reported flowing at a rate of 466 bbl per day of 33.6 degree gravity oil. A portion of the production is coming from a new and deeper Eocene sand at 10,565-11,006 ft. The balance of the production stems from the regular Eocene sand opened in an interval between 10,266-10,558 ft. The find may open an area for development previously not considered within the limits of the Eocene pool at Wheeler Ridge.

★ Hancock Oil Company as the operator, in a joint venture with General Petroleum Corporation and Union Oil Company, completed a discovery on the northeast flank of the Long Beach structure, Signal 52, for initial rate of 3077 bbl per day of 32 degree gravity crude. The producing zone correlates with the Long Beach Deep Zone, but the production area, which is controlled by faulting, is believed to be quite limited in extent, and is being developed under extremely competitive conditions. Two follow-up wells are being drilled.

Union Oil Company has completed one of the largest producing wells ever drilled in the South Mountain field, Ventura County, California. The well, Culbert 17, was completed flowing 22.2 degree gravity crude oil at the rate of 936 bbl a day. It was drilled to a total depth of 5864 ft and is producing through 1683 ft of perforated pipe.

CANADA

★ Union Oil Company of California and Hudson's Bay Oil and Gas Company are drilling two additional wells in the vicinity of their Liberal 15-31 discovery well in the South Sturgeon Lake area of Northeastern Alberta, Canada. Of great importance to the operators in the Sturgeon Lake area is the likelihood that a pipe line to transport oil production out of the area will probably be installed and in operation sometime this year. The Provinical Conservation Board is currently holding hearings on several applications which have been filed to build such a pipe line.

LOUISIANA

★ The Cormier No. 1, Continental test in the Rayne field of Acadia Parish, has completed as an excellent well from the Nodosaria sand. Tested on a 17/64-in. choke, potential was for over 4½ million feet of gas and 267 bbl of 49.7 deg distillate per day. Perforated in the interval 13,942-980, flowing tubing pressure was 3100 lb during the test.

★ Stanolind has completed a south flank producer on the Jefferson Island salt dome. The Lemaire well from a producing perforated interval from 8984-94 flowed 100 bbl per day of 34.5 deg crude through a 9/64-in. choke. A test of a deeper sand 9800-12 also showed for oil. Total depth of the well was given as 10,256.

OKLAHOMA

★ The Continental Oil Company has completed the Rose-Vose "5" No. 6, in the Golden Trend field of Garvin County at a total depth of 9487 ft. Completed through perforations in the 5½-in. casing in the interval 9351-9371 ft opposite the Springer zone, the new well was tested while flowing through a 20/64-in. choke for an IP of 187 bbl per day at a gas-oil ratio of 315 to 1. Corrected gravity was 37.8 deg.

★ Texas Company's No. 4 Tussy, Stephens County, has been completed in the First Goodwin flowing 120 bbl of oil and no water in 24 hours through 14-64 in. choke from perforations 5629-45 feet. Gravity was 38 degrees. Company has also completed No. 5 Graham, Stephens County, in the Hefner, flowing 123 bbl of oil and no water in 24 hours, quarter-inch choke from perforations 5797-808 feet.

Rotary Rigs Operating in Oil Fields of United States and Canada*

	Nov. 15	Nov. 22	Nov. 29	Dec. 6	Dec. 13	Dec. 20
Pacific Coast	142	140	140	143	149	150
Oklahoma	316	324	329	325	332	316
Kansas	175	183	184	190	190	193
Rocky Mountains	251	251	263	262	249	251
Canada	195	201	192	212	212	211
Ark-La-Tex	186	198	187	192	200	200
West Texas and New Mexico	497	512	500	512	523	535
Gulf Coast	548	564	544	565	577	599
Illinois	148	146	150	150	148	152
North Texas	301	319	315	339	370	356
Total	2759	2838	2804	2890	2950	2963

*As reported to the American Association of Oilwell Drilling Contractors by Hughes Tool Company

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RUNNING TOUR with MEN in the INDUSTRY

Newly elected officers for 1955 for the Pacific Petroleum Chapter, AIME, have been announced by **Milton Loy,** retiring chairman, as follows: Chairman, **H. M. Stanier,** Sunray Oil Corporation; council members, **Sam Patterson,** Bankline Oil Company and Milan G. Arthur, Union Oil Company.

V. E. Hanes has recently resigned as district geologist for Drilling & Exploration Company, Inc., in Midland, Texas, to become associated with the Nebo Oil Company of Dallas, Texas. He had been with the Magnolia Petroleum Company for six years prior to joining Drilling & Exploration.

H. L. "Ted" Fannin, Jr., was named as general land manager of Three States Natural Gas Company. Fannin, who had previously held a similar position with Great Western Drilling Company, will supervise land and leasing details of $3.1 million exploration program scheduled for 1954-55 in Colorado and Utah.

Cummins and Brinkerhoff announce the dissolution of partnership effective October 1, 1954. **Ira Brinkerhoff** will continue consulting in the San Jacinto Building, Houston, Texas, and Cummins will operate as **Ralph H. Cummins,** Inc., with offices in the Forth Worth National Bank Building, Fort Worth, Texas, and the Texas State Hotel, Houston, Texas.

The promotion of **Millard F. Westfall** to acting production superintendent for Husky Oil Company was announced. Westfall's promotion followed the transfer of **John R. Yoder** to Israel. Yoder is in charge of drilling operations for Israel-American Oil Corporation. Prior to joining Husky, Westfall was district engineer for Cities Service Oil Company, Texas district, Graham, Texas. He received his engineering degree at the University of Colorado in 1942.

J. B. Lassiter, Jr., has joined the staff of Lion Oil Company's reservoir engineering department in El Dorado, Arkansas. Lassiter will be senior engineer in the reserve and economics section.

He was graduated from Texas A & M College with a BS degree in petroleum engineering in 1940. He worked for Phillips Petroleum Company in south Arkansas, north Louisiana, and east Texas, and prior to joining Lion was, for several years, chief engineer of Marine Oil Company in El Dorado.

L. B. McCammon, manager of the products distribution department of The Ohio Oil Company, retired December 1. He had completed 24 years' service with Ohio Oil. **M. D. King,** assistant manager of the products distribution department, succeeded McCammon as manager. McCammon joined Ohio in 1930 when the company acquired the properties of the Transcontinental Oil Company. He was vice president and director of Transcontinental from 1920 to 1930. King first worked for Ohio as messenger in the general office in 1926 between school terms at Findlay College. His continuous employment began in February 1931 as secretary in the refining and marketing department, Robinson, Illinois.

Appointments of **Marvin L. Brown** and **Lloyd E. Miller** as assistant division managers for Sun Oil Company's Canadian production division have been announced.

Brown has the title of assistant division manager-operating. He will continue to serve as superintendent of the operating department. Brown began his career with Sun more than 35 years ago. He was assigned to the Canadian division in October, 1951, as superintendent of production.

Miller's new title is assistant division manager-exploration. He also continues to serve as division chief geologist. He joined Sun in the southwest division office at Dallas shortly after graduation from the University of Minnesota with a B.A. degree in geology in 1937. In April, 1950, he was promoted to division chief geologist for the Canadian Production Division.

Richard Huntington Bosard has recently been employed by Lion Oil Company as an oil scout. Bosard, who will be attached to the district office at Billings, Montana, was educated at Eastern Montana College of Education and the University of Montana.

Humble Oil and Refining Company has announced the appointment of **W. T. McGarrahan,** roustabout gangpusher in the Athens district, East Texas division, to farm boss at Athens. He was replaced as roustabout gangpusher by **J. F. Mitchell,** roustabout at Athens. **A. H. Ilfrey,** senior petroleum engineer, Southwest Texas division office, was transferred to the Wink district, West Texas division, as district petroleum engineer. **Woodrow W. Sills,** toolpusher, Greta district, Southwest Texas division, was transferred to the Snyder district, West Texas division as toolpusher. **J. F. Matthews, Jr.,** civil engineer in the Greta district, was transferred to Louisiana division office as civil engineer.

J. M. Skipper, civil engineer in the Flour Bluff district, was transferred to the Grand Isle district, Louisiana division, as civil engineer. **C. D. Miller, Jr.,** draftsman in the Southwest Texas division, was transferred to the gas construction division, Houston, and promoted to junior civil engineer. **J. F. McPhail,** civil engineer in the Southwest Texas division office, was transferred to the Louisiana division office as civil engineer. **Edward E. Murray,** senior petroleum engineer, was transferred from the Conroe district to the Gulf Coast division office.

William S. Floyd, manager of Shell Oil Company's west coast purchasing department, has been appointed assistant director for materials of the Office of Defense Mobilization. **James R. Branine,** former Shell purchasing and stores representative in the New York area, succeeds Floyd as Shell's west coast purchasing manager.

J. E. Clark, until recently production manager of Shell's Denver, Colorado, exploration and production area, has been elected vice president in charge of the Midland, Texas area.

Stanwood I. Williams, president of Thomas P. Pike Drilling Company, Los Angeles, California, has been elected California chapter chairman for the American Association of Oil Well Drilling Contractors during the 1954-55 term.

Thomas N. Cook has been appointed special field service representative for the Pennsylvania Grade Crude Oil Association in the East Coast area. He succeeded **Jack F. Fallin,** who resigned to join the sales staff of United Refining Company, Warren, Pennsylvania. Cook has headquarters in New York City. He did undergraduate work at Gannon College, Erie, Pennsylvania, and Bowling Green University in Ohio.

C. B. Officer

Dr. Charles B. Officer, geophysicist with Woods Hole Oceanographic Institution, has been selected 1954-55 distinguished lecturer by the Society of Exploration Geophysicists, it was announced today by Carl Savit, Western Geophysical Company, Los Angeles, chairman of the SEG Distinguished Lecturers Committee. Officer has received the degrees of ScB. in Physics from Brown University, M.A. in physics from Wesleyan University, M.S. in physics from Yale University, the PhD. in geophysics from Columbia University. The 28-year-old scientist served two years as research associate at Lamont Geological Observatory of Columbia University. Since 1951 he has held the position of geophysicist at the Woods Hole Oceanographic Institution, engaged in research on various problems dealing with underwater sound transmission and submarine geophysics.

John Sloat, formerly manager of exploration for the Pacific Coast division of the Union Oil Company, has been appointed to the administrative staff of the company's western area exploration department which covers the Pacific coast, Rocky Mountain, Canadian division and unassigned areas. **Charles F. Manlove** and **Edward W. Scott** also have been appointed to the administrative staff. **John E. Kilkenny** has been appointed chief geologist, Pacific Coast division, and **Fred W. Bush,** formerly manager of exploration for the Williston Basin division has been appointed manager of lands for the Pacific Coast division and unassigned areas.

Appointment of **Max C. Sons** as an assistant chief of research of The Carter Oil Company research laboratory has been announced. He directs overall activities of the drilling research and recovery methods sections. **P. D. Baker** succeeded Sons as chief petroleum engineer for Carter and **G. C. Hollinger,** Shreveport, Louisiana, southern division engineer, became assistant chief petroleum engineer. **Marshall A. Jeffers,** Shreveport, was named southern division engineer, to succeed Hollinger. A graduate of the Missouri School of Mines, Jeffers joined Carter in 1939 and has done engineering work in Utah and Oklahoma.

Hugh Wilson has been named division geologist by Tide Water Associated Oil Company to direct geological activities for te firm's southern division.

K. A. Schmidt, former acting division geologist, has been placed in charge of the company's off-shore geological work.

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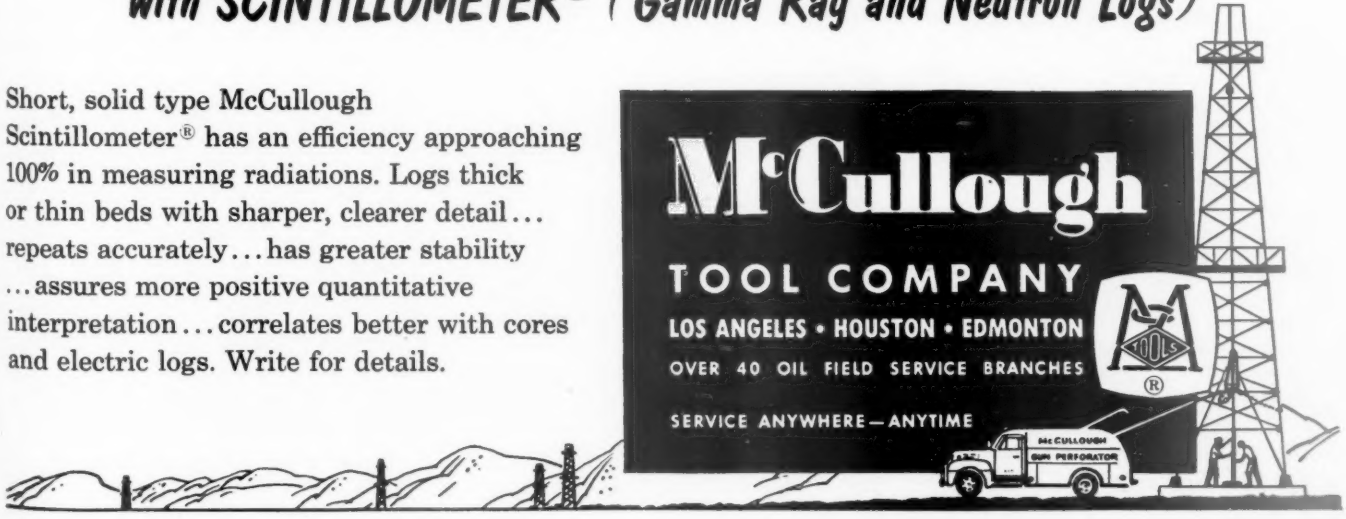


Equipment News Feature

100 Engineers See Casing Hanger Tests

A Houston manufacturer has recently completed a series of shop tests of their newly designed casing hanger, witnessed by more than 100 industry engineers.

The problem of suspension of long and heavy casing strings is one that is receiving increasing attention from design engineers in the industry. It is frequently necessary to run casing in wildcat wells, either as a protection string to guard against drilling trouble at depth or as completion strings for proper evaluation of questionable zones. Increases in drilling depths in recent years have highlighted difficulties of hanging these long strings with ease and safety and without damaging the hanging joint. Instances of abandonment and subsequent casing recovery operations where the hanging joint is severely bottle necked are on record. In some cases, loads have been so severe and so much beyond the design capacity of the casing hanger used that it has been necessary to actually destroy the hanger with an acetylene torch in order to free the top casing joint and recover the string.

Basically, the casing hanger has only two functions to perform—it supports a part or all of the uncemented casing weight, and it seals the annulus between the casing and the hole or outer casing string.

Various means of effecting this sealing action are currently in use. Some manufacturers locate the seal above, some below, the slips. Those seals placed below slips have at least two advantages: The slip area, which is already in compression from the horizontal slip forces, is protected from unexpected or accidental pressures from below; and the friction of the packing element aids in support of the suspended casing string.

Seals above the slips protect the slip area from test pressures which should always be of greater magnitude than anticipated formation pressures. If those upper seals are resting on top of the slips, however, there is an additional force, other than that due to suspended casing weight, applied to these slips from the hydrostatic testing that may be only partially dissipated by seal-bowl wall-pipe friction.

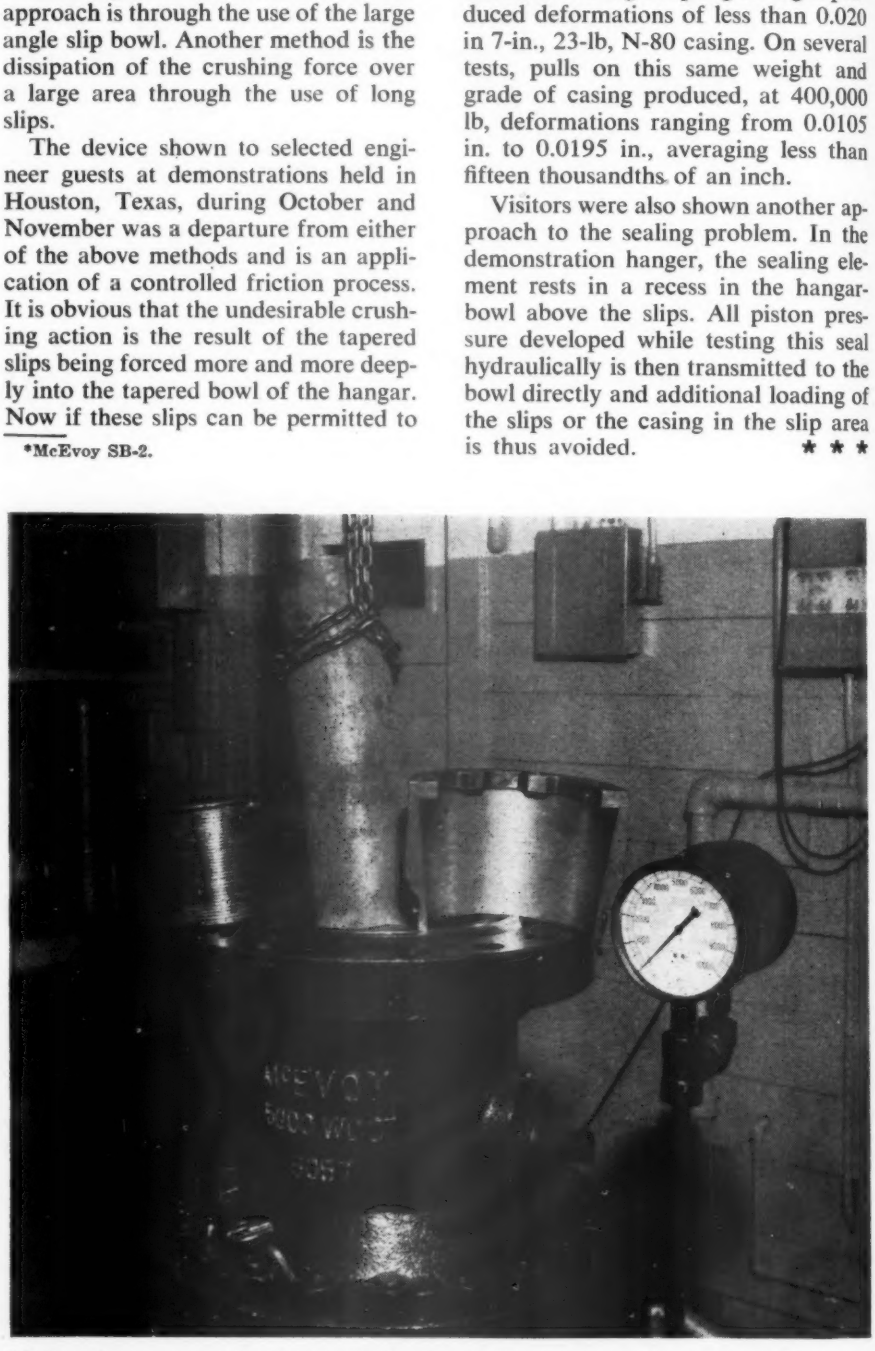
The actual suspension of the casing itself induces horizontal crushing forces which can develop considerable magnitude. Prior to the development of this hangar*, other manufacturers had used at least two other means of minimizing the effect of this force. One approach is through the use of the large angle slip bowl. Another method is the dissipation of the crushing force over a large area through the use of long slips.

The device shown to selected engineer guests at demonstrations held in Houston, Texas, during October and November was a departure from either of the above methods and is an application of a controlled friction process. It is obvious that the undesirable crushing action is the result of the tapered slips being forced more and more deeply into the tapered bowl of the hangar. Now if these slips can be permitted to go into this tapered bowl only far enough to assure a firm, even bite on the hanging casing joint, then stopped, the addition of weight to the hanging joint will produce little additional crushing action. The problem, however, was to secure the desired slip-bowl friction while simultaneously insuring the continued safe holding characteristics necessary in a casing hanger.

In the demonstrated hanger, this problem was solved by placing teeth on each side of the slip segments. Those on the pipe side are sharp and will immediately grip the casing. The back side teeth are not so sharp and dig into the bowl face only after the pipe has been gripped. In the public tests, loads in excess of long coupling strength produced deformations of less than 0.020 in 7-in., 23-lb, N-80 casing. On several tests, pulls on this same weight and grade of casing produced, at 400,000 lb, deformations ranging from 0.0105 in. to 0.0195 in., averaging less than fifteen thousandths of an inch.

Visitors were also shown another approach to the sealing problem. In the demonstration hanger, the sealing element rests in a recess in the hangar-bowl above the slips. All piston pressure developed while testing this seal hydraulically is then transmitted to the bowl directly and additional loading of the slips or the casing in the slip area is thus avoided. * * *

*McEvoy SB-2.



McEvoy hanger assembly showing back side of slip and inner side of bowl. Nipple has been subjected to a loading in excess of long coupling joint strength.

Refining . . . Petrochemical . . . Gas Processing

Hydrogen and Olefins From the Same Step

Hercules Powder and Blaw-Knox are offering processes for making hydrogen via the Society Belge de l'Azote continuous hydrogenation process, announced previously by Blaw-Knox for making fatty acids. Olefins come via dehydrogenation, thermally, of light liquid hydrocarbons to make ethylene, propylenes, etc. Separation of ethylene, for example, is carried out by cryogenic or by absorption methods. Higher temperatures possibly made practicable by use of the new alloy NA22H may make operative much higher capacities at higher temperatures than practiced formerly.

SO—the process of reducing hydrocarbons to their component parts or radicals, and reassembling those components in forms needed by our civilization progresses. As a prominent writer said nearly 30 years ago: "The products of the petroleum industry are and will be 'assembled products,' made up of unit materials reassembled to make the things we need." We are approaching that point, more rapidly than most of us think. Needless to remark, the process into which we have only begun to penetrate is inexorable.

★ ★ ★

The Octane Race — Where Is the "Finish Line?"

The striving for power efficiency, and for retail markets is driving the oil *and* the automotive industries into a continuous, ever-quickening, "wide-open throttle" contest to produce higher and higher efficiency in fuels and in engines—and to what purpose?

Instantly the reply comes from both "camps": "Of course, for better performance, for greater efficiency of engine operation, to conserve our petroleum resources; to utilize to the fullest the inherent power in the (fuel—engine design)." (Mark out one, depending on the industry to which the replier belongs.)

But *are* we utilizing the inherent power in either engine or fuel, to an economic purpose? Octane ratings run from the middle 80's to 95-96, in a very few instances slightly higher. Go down the line of the big companies and see the fabulous millions, as one reporter phrased it, "going into equipment to *improve quality* rather than hike production." Company 1, $90 millions; Company 2, $30 millions, "aimed at stepping up octane ratings"; Company 3, $2.4 millions for research facilities alone; Company 4, $165 millions; Company 5, no statement of dollars involved, but "A new premium gasoline . . . after the first of the year that will be . . . improved over current premium grades. We will not let competition get ahead of us, either." Average octane numbers will go up one to one-and-one-half numbers by spring (1955), says another executive, most certainly in the know. In five years, a very prominent engineer-scientist says, 100 octane number motor fuel will be on the market. Compression ratios are up, 7.5 to one, and 8.0 to one. Eight years ago the Ford had 100 hp motors; in 1954, 130 hp, and 1955 162 to 182, as compared to the 1951 "Cad." with 160 hp. Higher priced cars go to 255 hp or higher, 8.5 to one or high compression ratio.

These remarkable advances *could* be used to reduce engines sizes, increase fuel miles-per-gallon, improve economy. Who needs a car that will do 135 miles per hour, with 60-65 the legal maximum; those loafing horses in that engine are eating "feed," while they do not a lick of work.

But again, the automotive people have no choice; to meet competition they must supply performance; the customers in this country have not reached the point where they are willing to swap scintillating getaway for less cents per mile operating costs, so we have the Cadillacs, the Chryslers, Buicks, Fairlane Fords and others with more than half their horsepower loafing in its traces in order to beat the other guy to the getaway when the light changes.

And the saga goes on and on; the coming year will see more octane ratings from refineries, more horsepower in motor cars—FOR WHAT?

★ ★ ★

Standard Studies the Atom

So Standard Oil Development—research group extraordinary, for Standard Oil of New Jersey—will whittle at each side of the atomic Trojan Horse to see what can be done to utilize atomic energy for the advantage of the industry and the country. In other words, SODevCo is coppering both bets by building an atomic energy research laboratory in New Jersey. Probable theme-song for the new venture: "Can new and better chemical products, more powerful gasolines and better lubricants be extracted from petroleum via atomic energy?"

Big Boss Sulfur

As sulfuric acid goes, so goes (chemical) industry. "Bob" Frank, consultant and surveyor-extraordinary for Foster D. Snell, Inc., says (CW, 10-30-54) that by 1965 sulfuric acid production will reach 18.6 million annual tons; safety cushion needs demand that total capacity by that time shall be 23.2 million tons per year. The needs are spread across the face of the industry; phosphate fertilizers, also ammonium sulfate; rayon and other textiles are increasing, using more sulfuric; innumerable other products and divisions of the industry.

Regenerated acid will play a big part in future supplies. Sulphur from many sources must be produced in larger quantities, including natural gas and refinery gas potentialities.

★ ★ ★

Offshore Sulfur

Whether Shell Oil finds only sulfur or oil, or both, on its 10-year leases of potential sulfur-producing ocean bottim beyond the 10-mile limit, it should de well, thank you. Although Texas Gulf Sulfur Company asked that the offshore sulfur tracts be opened to bids, it did not submit any bid itself; only Shell's $1.2 million offer for 25,000 acres was submitted and accepted. Over a half a million acres went unsought. Upon production, Shell will pay Washington 7.5 per cent royalty on its sulfur sales.

★ ★ ★

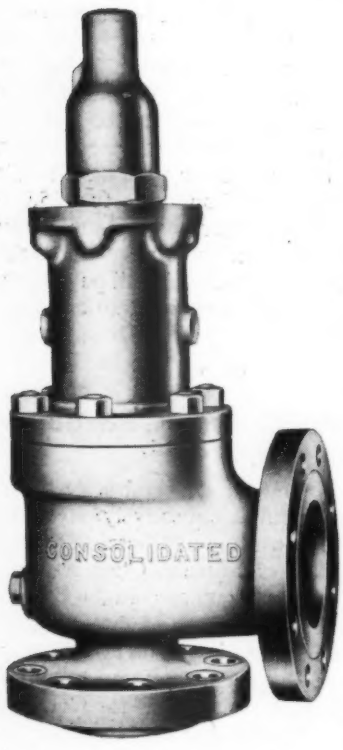
Should Chemists Bargain Collectively?

Would industrial chemists be better off by bargaining collectively? Recently American Institute of Chemists argued the matter extensively. Chemist-attorney Kegan said unions might be like spinach for chemists; might be "good for them" but they won't have any. Some of the pertinent—and potent—arguments against unions for technical people: "They ignore the law of supply and demand; if chemists are plentiful, what force can possibly keep salaries up?

Stated in the discussion by antagonists of professional unions: "Collective bargaining must be 'for the whole crowd and is thus inconsistent with merit increases for individuals'." One great stumbling block to unions' acceptance by technical people: "Who is to determine the 'merit' in 'merit increases' in salary?" (CW,12-11-54)

NOW... CONSOLIDATED SAFETY RELIEF VALVES in economical "2 in 1" design

Peak performance . . . positive valve action assured . . . even where discharge lines are long, or low "superimposed" back pressure exists in the relieving system.



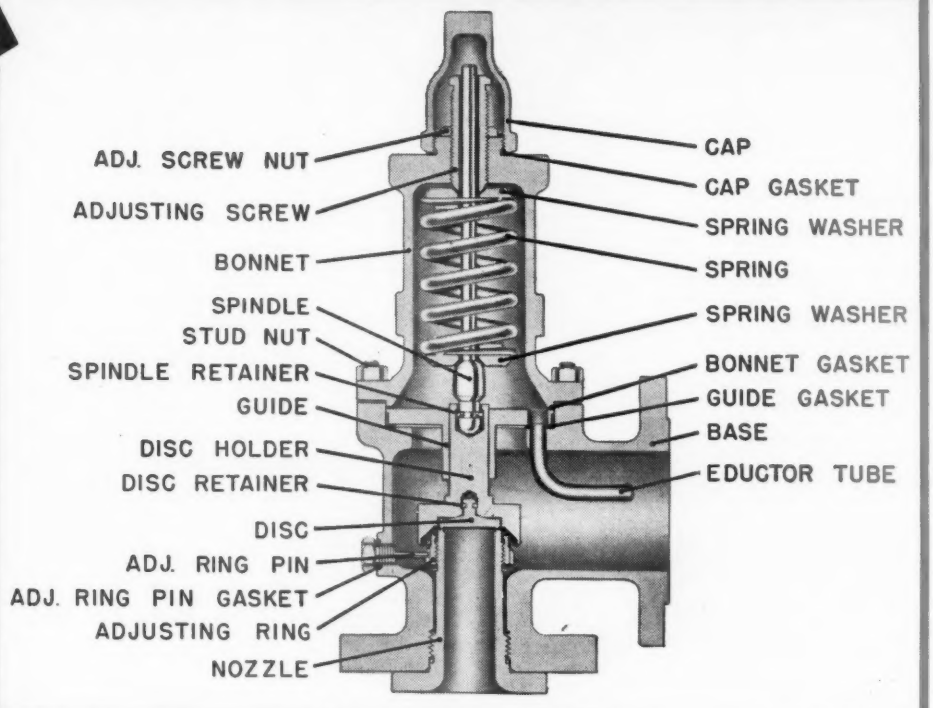
"Two-In-One" design, improved performance . . . the new Consolidated Safety Relief Valve is the result of over 4,000 flow tests in 5 years at West Edmond, Oklahoma. At the A.S.M.E.-approved testing station there, natural gas is available in flow capacities up to 35,000 cfm and pressures up to 500 psig. The A.S.M.E.-approved conditions, apparatus, and procedures permitted Consolidated engineers to test-develop and prove the full range of valve sizes and pressures in both Standard and Bellows designs.

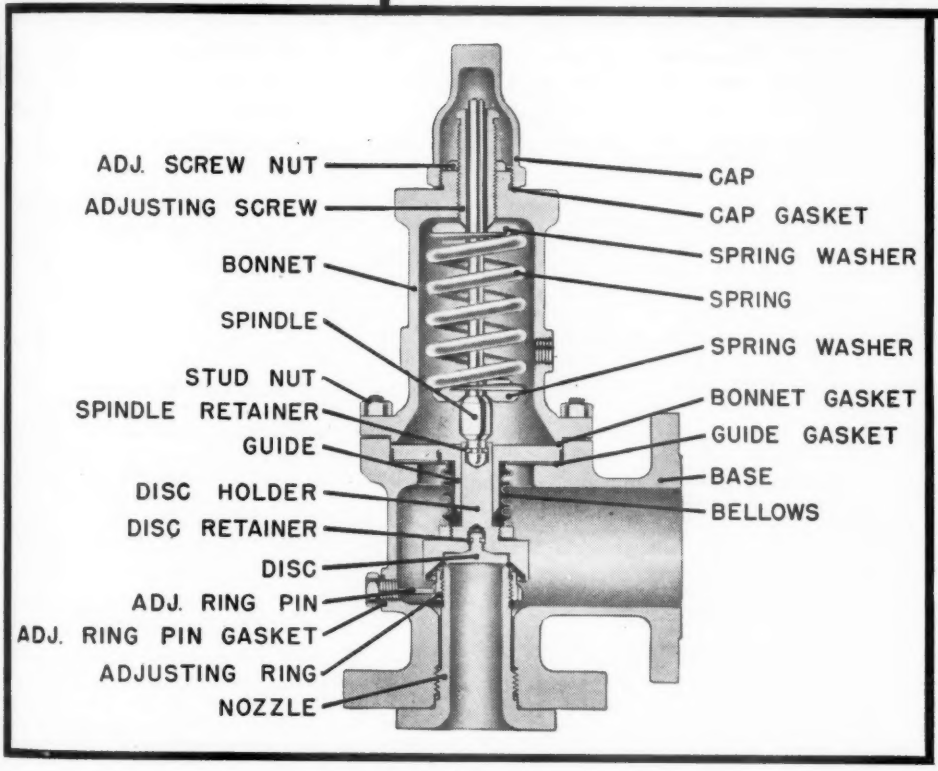
Interchangeability is so highly developed that the majority of Consolidated Standard Valves can be converted to the Bellows design, in the field, simply by installing the bellows. Each type has fewer functional parts than other comparable safety relief valves. Standardization of inlet and outlet center-to-face dimensions permits interchangeability with a large proportion of the valves of other manufacturers. Incorporated is an optically-ground flat seating surface that contributes to easier, more economical maintenance.

You can have the absolute protection and real economy of the thoroughly tried and proved Consolidated Safety Relief Valves for your plant today. Both Standard and Bellows types are available in sizes and pressures to meet requirements of the most advanced processing facilities. Write for full details. Ask for Catalog 1900.

CONSOLIDATED SAFETY RELIEF VALVES

STANDARD VALVE has an eductor tube that holds the pressure in the valve bonnet to approximately atmospheric pressure; thus only the force of the spring controls the valve. Valve action is improved and stabilized . . . repetitive flow capacity is provided . . . a new high in operational dependability is assured. Even under repeated popping of the valve, set pressure and blowdown are consistent. The valve will open to full capacity at 3% overpressure regardless of the position of the adjusting ring.





BELLOWS VALVE is like the Standard but has a durable, two-ply stainless steel sealing bellows which effectively isolates from the valve's working parts any contaminants, corrosion, or viscous fluids. The bellows is balanced with the seating surface: set pressure of the valve is not affected by back pressure, whether constant or variable. Consequently, smaller discharge piping can be used, thus reducing the cost of pressure-relieving systems.

Certified and Approved

Both Standard and Bellows Valves are approved under A.P.I.-A.S.M.E. Unfired Pressure Vessel Codes, A.S.M.E. Unfired Pressure Vessel Code and are certified by the National Board of Boiler and Pressure Vessel Inspectors.

CONSOLIDATED 1879 U.S.A.

A PRODUCT OF MANNING, MAXWELL & MOORE, INC.

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MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, *Stratford, Conn.* 'HANCOCK' VALVES, *Watertown, Mass.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*

REFINERY PLANTS SCHEDULED FOR COMPLETION

Platformer-Hydrogen. A new Hydrogen unit, connected to and with a platformer unit has gone on stream at the Lima, Ohio, refinery of Standard of Ohio. These two interconnected units each aid the other to function; excess of hydrogen from the platformer is employed in the Hydrobon unit to treat raw naphtha; in turn this treated naphtha is processed in the platformer to the extent of 12,000 of the 13,000 bbl per day throughput of the Hydrobon unit. The other 1000 bbl is used as burning oil. Units designed by UOP, built by Procon, Inc.

★ ★ ★

Gulf builds four cat units. Four new catalytic reforming units, designed for UOP plaforming process, are to be built by Gulf Oil Corporation. These units include one at Port Arthur, Texas, 29,000 bbl per day, to be completed in spring, 1955. Philadelphia, Pennsylvania, refinery is building a 16,000 bbl per day plant to go on stream before year's end. Toledo and Cincinnati, Ohio, refineries each are building 10,000 bbl per day units to be completed in the spring of 1955. The Port Arthur unit is being built by Fluor Corporation, the other three by Procon Corporation.

★ ★ ★

Pakistan Gas processing unit. A gas-gathering processing system is to be built for Pakistan Petroleum, Ltd., by Hudson Engineering Corporation of Houston, according to advices received. Processed gas will be piped to Karachi via Hyderabad, 350 miles from the Sui field where it originates. Project will cost about $30,000,000 and will supply this city of 1,500,000 people. The job will be completed by May, 1955. The Sui field in Baluchistan has been proved to have two trillion cu ft of gas reserve and by reducing or eliminating the need for importation of coal, and giving raw material for synthetic ammonia as agricultural fertilizer, and other chemical products, will boost the economy of West Pakistan tremendously. Equipment will be shipped 11,000 miles from this country to the unit site.

★ ★ ★

Great Automotive Laboratory. Twenty-seven engine test cells plus ten maintenance-wing rooms will be installed in the Gulf Research and Development Laboratory at Harmarville, Pennsylvania, up-river from Pittsburgh. A contract with The Trimble Company has been let, and work has begun on the expansion. Three cold rooms permit testing at down to 70 F below zero. Electricity at voltages from 110 to 2300 will be installed. Blending building units, a new tank farm and steam generating unit will be included.

★ ★ ★

Cities Service Gasoline Plant on Stream. The Gaines Company, West Texas natural gasoline plant, capacity 21 million cu ft of raw gas, went on stream recently. Seven other oil companies are part owners of this plant, which Cities Service will operate. Guy M. Duren is plant superintendent, plant is located five miles northwest of Seminole, Texas.

Gulf Oil Corporation is employing five large Worthington centrifugal compressors to handle the gases in its ethylene plant. Photo shows compressor handling charge gas and shows water nozzle inlets. The five units total nearly 20,000 hp and operate at about 5500 rpm to more than 9000 rpm.

Second and Third Platformers on Stream. Quaker State Oil Refining Corporation has begun operation of platformer units No. 2 and 3, at Emlenton, Pennsylvania, and St. Marys, West Virginia. Each has a capacity of 850 bbl per day; a 1500 bbl per day unit began operating at Farmer's Valley, Pennsylvania, last July. All units designed, engineered, and licensed by UOP. Procon, Inc., built them.

★ ★ ★

Sinclair Refining Company has contracted with Tuloma Builders, Inc., of Tulsa, Oklahoma, to add an extension to its demulsifying plant at Sand Springs, suburb of Tulsa.

★ ★ ★

Standard Oil Company of California will build the first complete oil refinery in Hawaii. A capacity of 20,000-30,000 bbl per day is planned, cost to be $25-$30 million. It will process gasoline, gas oil, fuel oil in quantities to meet most or all the territory's needs for these products. Plant site is Honolulu; no contracts for design or construction let so far as is announced.

★ ★ ★

Texas Natural Gasoline Corporation has begun building a natural gasoline plant in Coke County to process gas from Jameson Strawn Sand Field and Fuller Coke Strawn Sand Field, about 70,000,000 cu ft daily. Natural gasoline, butane, i-butane and propane will be recovered from the well gas. It is estimated that 375-400 wells will be in these fields when they are fully developed. Gathering system will be operating by March 1, fractionation units by August, 1955.

Big Platformer Building for Champlin. A 5000 bbl per day platformer is under contract to be built for Champlin Refining Company by Southwestern Engineering Company of Los Angeles, California, at the refinery, Enid, Oklahoma. Unit will cost about $700,000, to be completed by about April, 1955.

★ ★ ★

New Platformer for Japan. The fourth platformer unit went into operation for Mitsubishi Oil Company, of Kawasaki, Japan, recently. The 1500 bbl per day unit will process naphtha from Arabian crudes. Unit was designed, engineered, and licensed by UOP, built by Japan Gasoline Company.

★ ★ ★

U. S. Steel Corporation is building a 200-ton per day ammonia plant at Geneva, Utah. It was designed by Blaw-Knox Company, and is to be the largest of its kind in the United States. Construction is to begin "early in 1955."

★ ★ ★

Storage, Pipe Line, Loading, Pumping System. A system for pumping, loading, storing, etc., from Bayway, refinery of Esso Standard Oil, to its Rahway Tank Field has been completed for Esso Standard Oil Company by the Kuljian Corporation of Philadelphia, Pennsylvania. Eighteen tanks of all sorts, including a 5000-bbl combined products tank and others of 150,000 bbl capacity each; a 30-inch main pipe line, a network of thousands of feet of smaller lines; and a central automatic control house to handle all blending, loading-unloading. Farm occupies a million-plus square feet of area.

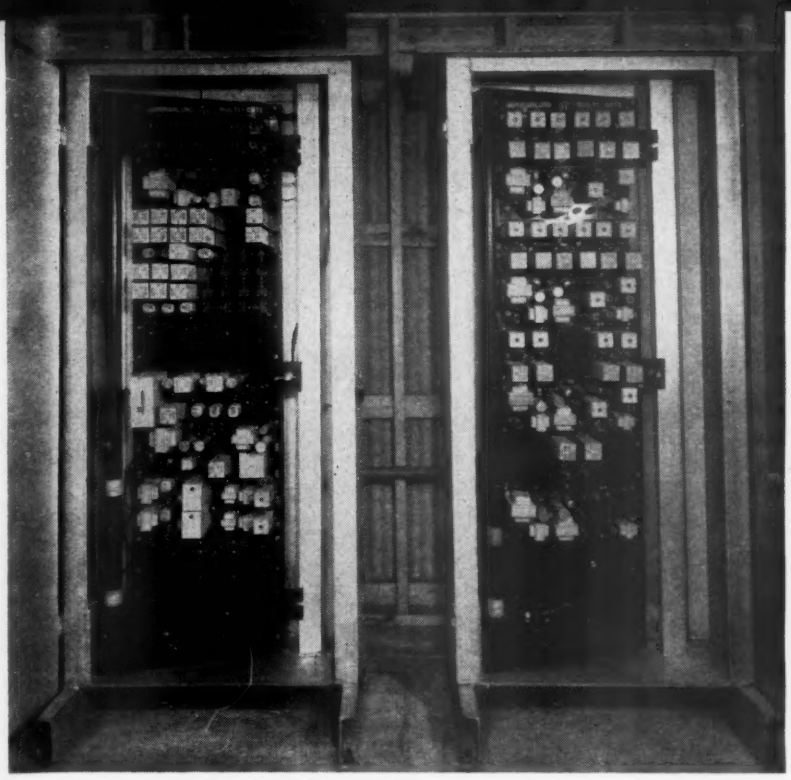

FIG. 1. Close-up of Master Station terminal equipment, Magnolia's Beaumont, Texas, refinery. Remote control coordinates widespread activties.

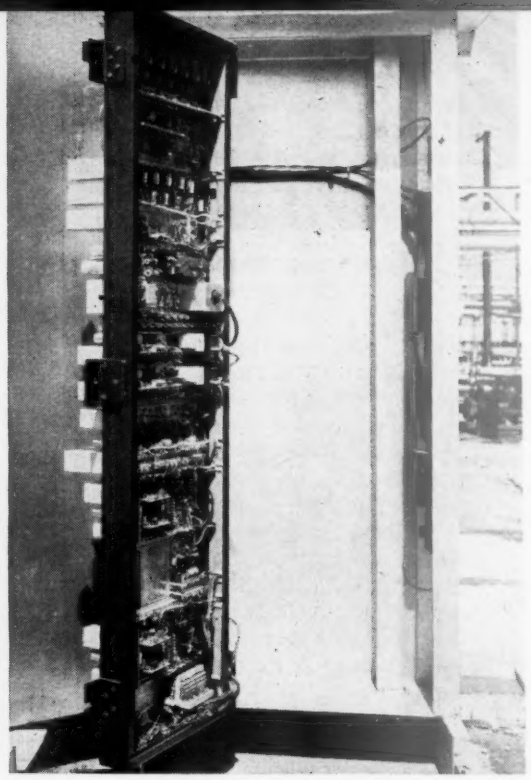

FIG. 2. Remote Station terminal equipment, showing swing-door type rack that provides good accessibility.

P 749.2

Electronic Control of Refinery Pumps

Remote control reduces number of workmen needed; speeds greatly delivery of product streams, and eliminates operating hazards

JOHN PETROVSEK*

THE petroleum industry has been one of the leaders in accepting electronics to help it save time and effort, and to produce greater overall system coordination.

Remote control is particularly valuable in all those industries that have widespread physical facilities, such as refineries, pipe lines, railroads, and public utilities. The substitution of electronic control equipment to operate pumps, valves, switches, and other functions remotely is being made rapidly. This type of equipment provides the advantages of immediate and direct operation of important functions from control centers where all activities are easily coordinated.

The Magnolia Petroleum Company refinery in Beaumont, Texas, planned to build a new truck loading terminal at the refinery, but wanted to move it out of the congested tank area. Separating the truck rack from the tanks and pumps, however, would make it necessary to add an additional man per shift unless some satisfactory remote control system could be installed economically. It was also brought out that operations would at times, especially in bad weather, have to wait for this man to move from one pump location to another.

As a result of "Multi-gate" remote control equipment,* the truck rack operator now has only to push a button corresponding to the type of fuel required. The remote pumps at the tank site are activitated and the required fuel is delivered immediately at the truck rack. Installation of this control equipment, operating only to control

*Communications Supervisor, Magnolia Petroleum Company, Beaumont, Texas.

EXCLUSIVE

*Designed and supplied by the Hammerlund Manufacturing Company.

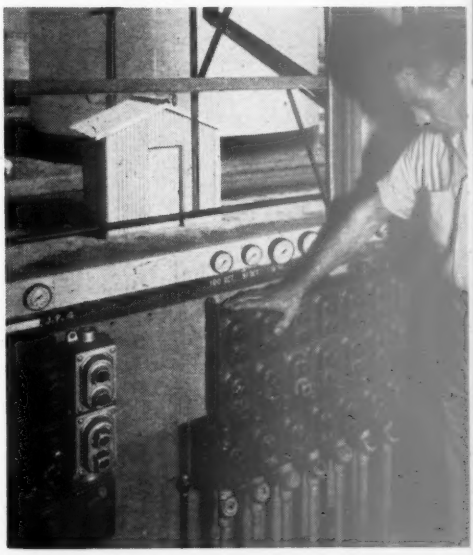

FIG. 3. Controls and supervisory indication lamps located on the loading dock for gasoline tank trucks at Beaumont refinery.

the pumps, at each of 2 separate sites, both approximately 2000 ft away, "off" and "on" as required, made it unnecessary to employ this additional man per shift and also eliminated the possibility of "human error" in the telephoned orders between the man at the truck rack and the man at the pump site. A remote control system was better from the safety standpoint as the truck rack operator could stop the pumps immediately in case of an emergency without the delay of making a telephone call to the man to stop the pumps. An Audio-tone system was selected for a number of reasons:

1. The danger resulting from dc pulses about a refinery area were eliminated by using Audio-tones in the range of 2000 to 6000 cycles per second.

2. Audio-tones made it possible to perform a number of functions using a single rented telephone line, thus reducing the monthly rental costs.

3. The system could be extended at any time without adding additional communications lines, or communication lines could be changed over to two-way radio or microwave without obsoleting the equipment.

The term "Multi-Gate" indicates that two audio-tones are used for each function. The first, or primary pulse, selects one (or more) receiver sections at a remote point, and through the operation of electronic gate makes it responsive to a subsequent signal. The time required for transmission of a single, complete primary signal is approximately five-tenths of a second. The second tone performs the required switching function in approximately three-tenths of a second only after the first tone has been present five-tenths of a second. Each set of two tones is transmitted using only a single push-button.

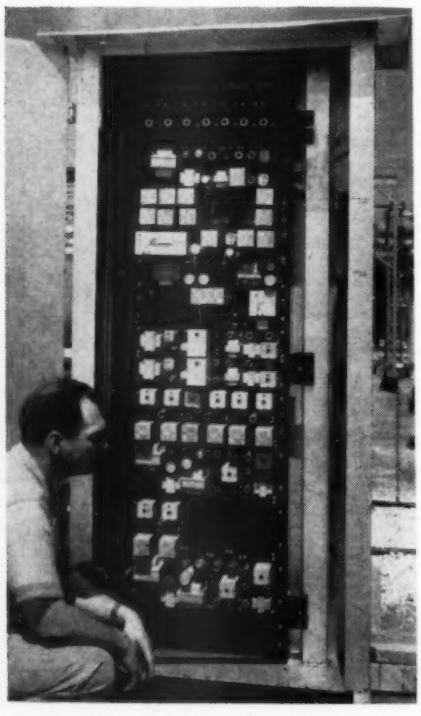

FIG. 4. Supervisor Petrovsek looking over a remote control terminal.

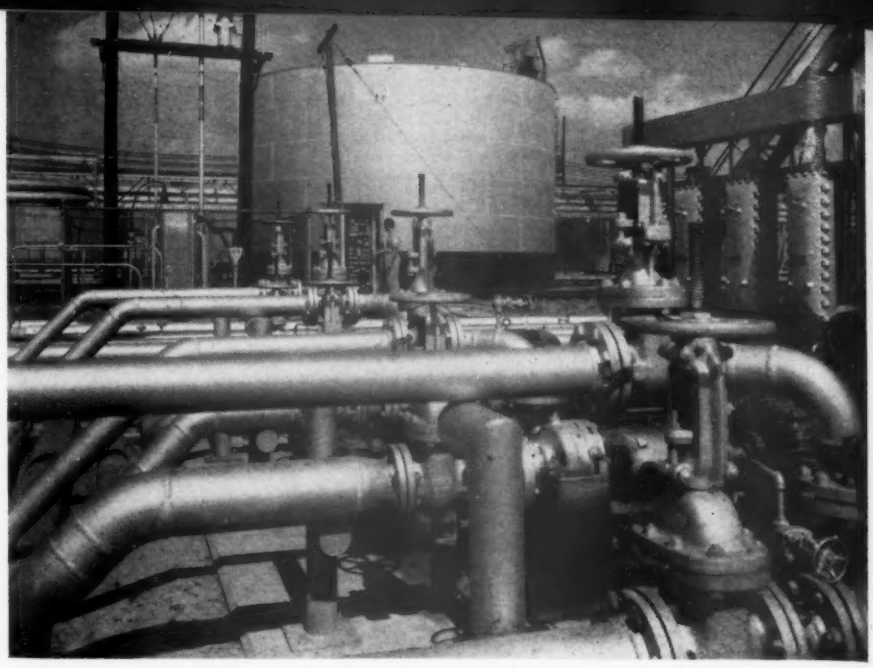

FIG. 5. Supervisor Petrovsek, center background, checks remote station equipment; right front shows pump motors controlled by equipment in explosion-proof building at right.

Up to 21 on-off functions can be performed by one system making use of no more than 7 different frequencies (taking two at a time).

This type of dual-tone operation reduces to a minimum the possibility of false operation resulting from circuit noise, induced voltages, transient pulses, voice or modulated signals, and other possible sources of interference.

The basic system consists of a transmitting unit to send automatically a standard sequence of two pulses at proper frequencies corresponding to the called station and one or more receiving units that are responsive to such coded pulses. A receiving section is installed at each of the two remote points.

Supervisory indications that the functions requested have actually been performed are received at the dock (master station) as a result of adding transmitting facilities at the remote points and receiving units at the loading dock. Indicating lamps verify that the operation has taken place.

Transmitter

When keyed, the remote control tone transmitter sends two-tones sequentially that are suitably timed to activate a remote tone receiver. An external programming system selects the proper tones to be transmitted and to key the tone transmitter at the desired instant.

Data Storage

A system of data or information storage is provided to make it possible to simultaneously select a number of functions to provide any of the number of different types of fuel to the loading dock. The master station incorporates two data memory storage units. For this specific installation one of them is capable of storing seven pairs of on-off functions but is set up at present to provide only five pairs. The second unit, also capable of being expanded to seven on-off functions, is being used for storing three on-off functions.

The 7 tone generators at the master station have frequencies from 2000 to 2600 cycles, 100 cycle apart. Frequency assignments for the two remote stations are between point 2700 and 3300 cycles 100 cycles apart.

As an example, one "on" function at pump station 1 would be performed by a primary gate frequency of 2000 cycles and a secondary gate frequency of 2100 cycles. To turn "off" the same function (a pump) the same primary gate frequency of 2000 cycles is used, but a 2200 cycles secondary gate frequency.

After the fail-safe system has been placed in operative condition, pushing any of the function select or buttons at the master station will operate the data storage relays. These relays energize the memory indicators that indicate visually the functions that have occurred. If the system is not busy transmitting verifications from the remotes to the master, the master station program allows the function program to seek out the stored orders and transmit the orders in coded pulses to the remote stations.

When the function program starts

XUM

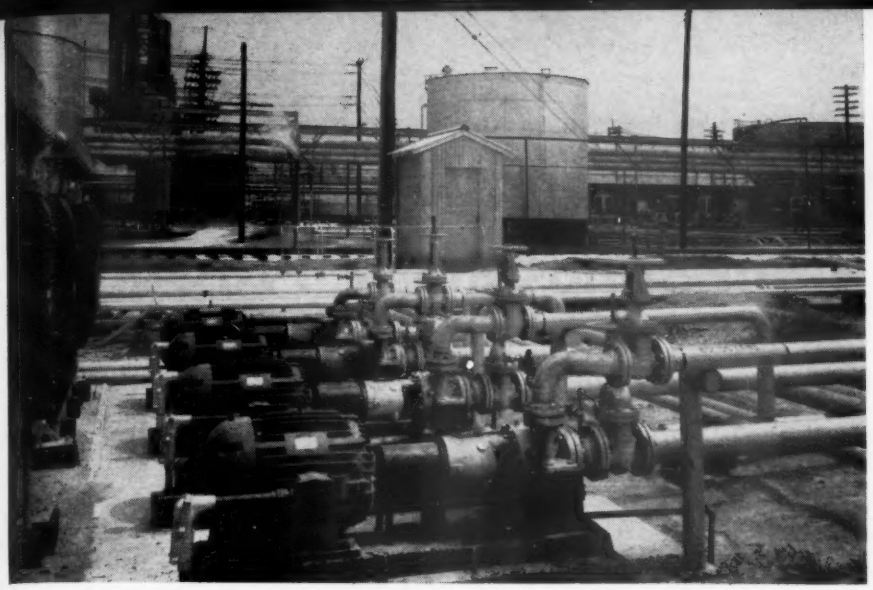

FIG. 6. Contact units at remote station, for controlling pump motors located in housing at left. Terminal equipment in house, center background.

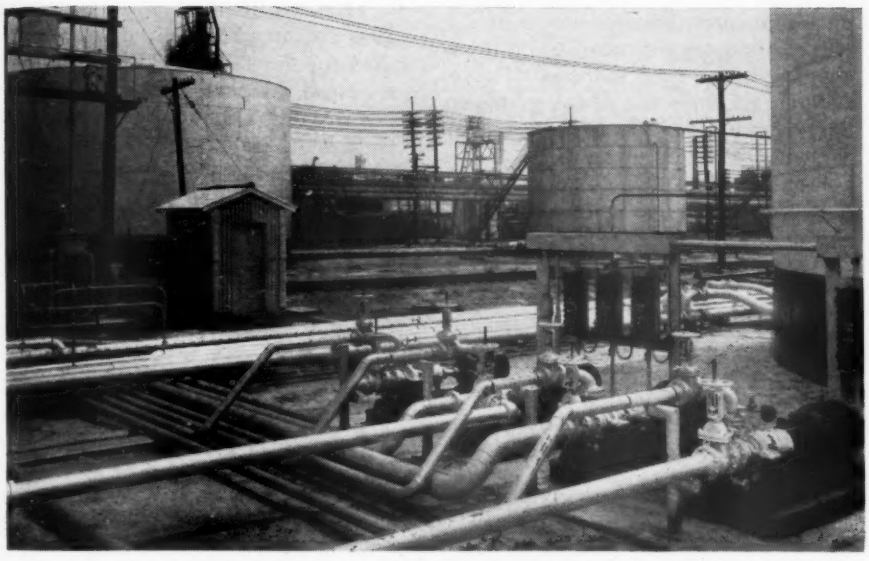

FIG. 7. Pumps at Magnolia plant controlled by audio-tones from the loading dock equipment.

FIG. 8. Loading a gasoline truck at Beaumont plant, with Master station control equipment in house at left.

its "seeking" operations, the station program keys the busy coder and places a busy tone on the transmission line. This prevents the remote stations from sending until the master station has transmitted all stored orders and removed the busy tone.

The tone and pulse coded orders are received at both remote stations and are translated into relay operations in the function decoder. If the required function is not happening, the control machinery is immediately required to perform that function. If that function is already happening, the machinery remains in that condition. In either case, information is stored in the data storage that indicates the order has been performed. If the busy tone is present, the verification program is held inoperative until after the busy tone is removed from the transmission line.

After the tone is ceased, the station program allows the verification program to "seek out" the verifications and causes the local busy tone to be placed on the verification line until all verifications are sent. The verifications are sent to the transmission line and then to the master station. Here, the verifications are de-coded by the verifications decoder and presented visually by the verification indicators. In general, the remote units operate very much like the master.

Fail-Safe System

Presence of a fail-safe system insures that all equipment performing operations at the remote stations will be turned "off" if the transmission line should fail, power fails at either master or remote station, or if the emergency button is operated at the master or either of the remote stations.

Fail-safe indications may be initiated from any station by depressing the emergency button for approximately one second. If no failure has occurred in the transmission line or fail-safe units, the fail-safe indications will lock in all stations allowing the remote station to cease their "off" function output and to turn operation "on" or "off" as ordered by the master station. If failure should occur in the transmission line or fail-safe equipment after starting, the fail-safe indications will be removed, producing off function output in all channels of the remote stations.

Should failures occur in other than the transmission lines or fail-safe units, the remote stations may be forced to produce "off" function outputs by depressing the emergency stop button located on the master control board and in both remote stations.

When fail-safe indications are not present, the failure alarms located in the master in both remote stations will light.

Two basic features, carefully predetermined for the equipment, were flexibility and versatility. Because it is designed on the building block-principal, using standard sections in individually unique combinations, great flexibility has been achieved, and for all practical purposes a custom installation was obtained. * * *

Comparison of TBP and Engler Type Distillations at Subatmospheric Pressures

Engler distillations vary little with pressure change; TBP curves may be developed from Engler vacuum distillation data

H. A. OEHLER* and M. VAN WINKLE**

An experimental investigation of the relationship between true boiling point and Engler type analytical distillation curves of a number of petroleum oil stocks was conducted. TBP distillations were conducted at 50 mm Hg pressure in an Oldershaw, 15 perforated plate column, and Engler type distillations on the same stocks were determined at 760, 400, 200, 100, and 50 mm Hg.

A correlation of the 50 per cent boiling temperature of the 50 mm Hg TBP distillation with the 50 per cent boiling temperatures of the Engler type distillations was derived and is reported here.

It was found that the slopes of the Engler type distillation curves did not vary with pressure (within the estimated limits of accuracy of the tests).

The correlation is useful in transposing from analytical vacuum Engler distillation data to true boiling point distillation or from TBP data to vacuum Engler data.

PETROLEUM oil and crude oil evaluation distillations are usually run at two pressures — atmospheric pressure for the low boiling fractions and at some subatmospheric pressure for the higher boiling fractions. In order to obtain continuous curves at some pressure, usually atmospheric, the data obtained at subatmospheric pressure must be transposed to the higher pressure.

In the event a distillation setup and method is used which approximates true boiling point distillation operation, where any point on the curve represents a compound or pseudo compound boiling at the indicated temperature at the pressure of the distillation, transposition can be made to other pressures by means of a vapor pressure chart. If the distillation is conducted under conditions where only a partial approach to fractionation is encountered, and such is the usual case, accurate transposition of the points on the curve to a different pressure by means of a vapor pressure chart can not be made as the curve does not represent a series of compounds boiling at the indicated temperatures but something between an equilibrium flash and TBP curve.

The common method of transposition is to transpose the vacuum analytical curve, commonly called a TBP curve whether it is or not, by means of vapor pressure relations and using general slope and 50 per cent boiling point correlations at atmospheric pressure, determine the ASTM or Engler curves at atmospheric pressure. These curves can then be used for product specification evaluation.

In many cases the original evaluation curves are run under vacuum conditions which approximate vacuum Engler operation. The curves thus determined are transposed to atmospheric pressure curves and the TBP-ASTM atmospheric slope and 50 per cent correlations are used to derive the atmospheric TBP curves. This is not accurate because of the reasons stated previously.

This investigation was initiated to determine a more accurate method of transposition of vacuum Engler type or ASTM distillation data to atmospheric TBP distillation data.

Stocks

The 29 stocks used in this investigation were supplied by the Pan American Refining Corporation and range in properties from those of heavy naphthas to reduced crude oils and include virgin stocks and cracked stocks. The analytical data on the stocks are included in Table 1.

Apparatus

TBP Distillation. The Oldershaw glass columns 25 mm in diameter were used for the vacuum TBP distillations for check purposes. Fifteen perforated plates with 42-0.85 mm holes in each plate were sealed in each of the columns. Each plate was equipped with a baffle to direct the flow of liquid, a weir to maintain liquid head on the plate, and a down pipe to supply liquid to the plate below. For complete description see references 5, 6.

Reflux rate was controlled by a Flexopulse timing device that provided intermittant distillate product take off. Vacuum was maintained by a controlled vacuum system and was connected into the system to the top of the column through a vapor trap and to the vacuum surge and vacuum receivers.

Pressure was read from a differential manometer and temperatures were read from calibrated thermocouples and calibrated ASTM distillation thermometers.

Engler Type Distillation. The equipment used in the vacuum Engler type distillations is the same as that used for the "Tentative Method Proposed for Reduced Pressure Distillation of Petroleum Products" — ASTM Distillation Method D 1160-52T[1].

Procedure

TBP Distillation. A brief outline of the operating procedure is as follows: Duplicate samples of 400 ml of oil to be distilled were charged to the clean, dry boiling flasks and the flasks joined to the column. (When the oil was too viscous for accurate volumetric measurement, the oils were weighed into the flasks.) The vacuum system was turned on and the columns allowed to reach the desired pressure of 50 mm Hg.

The reflux head was set on total reflux and the heat turned on. Heating

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TABLE 1. Distillation and inspection Data.

Stock no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
API gravity	44.9	41.7	34.1	31.9	32.9	36.3	25.8	32.2	28.9	30.4	24.0	31.7	29.1	31.3
Molecular weight	173	165	226	191	175	218	297	217	280	252	344	196	196	193
Engler dist'n., 760 mm, F														
IBP	343	305	385	320	356	392	426	390	306	264	542	221	236	265
Percent														
10	374	370	468	401	399	463	564	470	496	476	623	388	414	423
30	393	405	507	450	429	495	622	500	571	535	686	454	468	464
50	412	429	538	493	456	517	677	523	635	584	714	504	507	489
70	439	454	570	538	486	542	720	555	702	639	...	558	546	523
90	481	491	618	617	542	584	...	625	...	732	...	632	608	605
EP	517	531	675	665	608	648	...	701	...	732	...	698	686	676
TBP dist'n, 50 mm, F														
IBP	128	100	185	150	124	162	242	195	162	126	341	101	109	148
Percent														
10	198	195	271	211	194	274	363	276	301	225	361	212	214	232
30	232	241	328	288	258	330	445	330	393	352	515	290	292	294
50	262	373	377	340	293	357	525	362	464	420	599	345	346	329
70	300	307	417	398	332	391	618	402	553	490	646	411	394	372
90	350	352	478	497	395	442	...	483	...	...	...	510	478	462
Engler vacuum 50 percent temp														
50 mm	263	275	372	337	293	352	508	356	455	413	573	345	343	328
100 mm	298	310	406	365	325	387	545	392	491	449	612	379	380	363
200 mm	335	348	445	401	362	426	588	431	537	488	654	419	418	398
400 mm	371	384	489	444	409	470	635	477	582	532	691	458	456	437
760 mm	412	429	538	493	456	517	677	523	635	584	714	504	507	489
Slope data deg percent														
TBP 50 mm	1.7	1.9	2.4	3.1	2.3	2.0	4.3	2.1	4.2	4.4	4.9	3.3	3.0	3.5
Engler 50 mm	1.1	1.3	1.6	2.2	1.4	1.2	3.3	1.3	3.7	2.8	3.3	2.7	2.1	1.6
Engler 100 mm	1.0	1.3	1.6	2.2	1.4	1.3	3.3	1.4	3.8	2.7	3.2	2.7	2.1	1.6
Engler 200 mm	1.1	1.3	1.7	2.2	1.4	1.3	3.2	1.4	3.8	2.8	...	2.7	2.1	1.6
Engler 400 mm	1.1	1.3	1.7	2.3	1.4	1.3	3.1	1.4	3.7	2.8	...	2.8	2.1	1.6
Engler 760 mm	1.1	1.4	1.7	2.3	1.5	1.3	(2.6)	1.4	(3.4)	2.7	...	2.9	2.2	1.7

TABLE 1. Distillation and inspection data—(Continued)

Stock no.	15	16	17	18	19	20	21	22	23	24	25	26	27	28
API gravity	28.6	24.6	34.0	37.3	45.8	16.0	15.3	24.5	18.5	21.7	17.4	47.5	40.0	33.9
Molecular weight	208	288	148	227	174	158	309	330	257	339	224	143	185	252
Engler dist'n., 760 mm, F														
IBP	420	547	361	320	318	400	492	434	381	496	336	326	376	382
Percent														
10	471	605	371	384	356	424	630	542	544	640	472	336	417	519
30	497	640	379	430	386	437	694	626	590	682	524	342	438	557
50	523	667	386	535	413	451	730	696	629	710	580	348	455	575
70	555	688	394	642	449	472	756	...	661	734	665	355	472	593
90	602	709	408	...	519	563	...	...	709	...	...	366	499	622
EP	636	714	443	718	615	692	...	...	725	...	727	401	531	658
TBP dist'n., 50 mm, F														
IBP	210	337	181	109	121	168	243	235	220	244	188	129	152	175
Percent														
10	278	402	206	214	170	239	413	340	326	414	254	178	242	328
30	324	466	224	239	228	263	511	457	401	510	332	197	278	381
50	359	514	240	359	254	288	581	568	458	560	416	210	306	413
70	402	548	253	475	298	308	631	655	509	619	507	223	330	444
90	458	...	284	...	361	381	...	...	585	...	...	240	358	482
Engler vacuum 50 percent temp														
50 mm	356	494	241	357	257	289	561	549	452	541	407	211	304	405
100 mm	389	531	274	395	288	321	597	585	487	574	439	239	335	439
200 mm	429	573	310	439	323	363	641	618	529	618	479	271	369	482
400 mm	473	620	347	486	363	405	682	663	573	661	529	308	411	524
760 mm	523	667	386	535	413	451	730	696	629	710	580	348	455	575
Slope data deg percent														
TBP 50 mm	2.1	2.4	0.8	4.4	2.1	1.2	3.6	5.3	3.1	3.4	4.2	0.8	1.5	1.9
Engler 50 mm	1.3	1.4	0.4	4.2	1.5	0.8	2.6	4.6	2.1	2.2	3.2	0.3	0.9	1.2
Engler 100 mm	1.4	1.4	0.4	4.1	1.5	0.8	2.6	4.6	2.1	2.2	3.2	0.3	0.9	1.2
Engler 200 mm	1.4	1.4	0.4	4.2	1.5	0.8	2.4	4.4	2.1	2.1	3.3	0.3	0.9	1.3
Engler 400 mm	1.4	1.4	0.4	4.3	1.6	0.8	2.2	(3.6)	2.0	1.8	3.2	0.3	0.9	1.3
Engler 760 mm	1.4	1.4	0.4	4.3	1.6	0.8	2.1	...	2.0	1.6	3.2	0.3	0.9	1.2

was continued until the vapors reached the condenser. This normally required 40 to 50 min. The column was operated at total reflux for approximately 15 min and then the reflux timer, set for a reflux ratio of 10:1, began to operate.

Product rate was adjusted by the rate of heating to 4-5 ml per minute. Temperatures were read at cut points corresponding to each 5 per cent of the original charge distilled, until 90 per cent of the charge was recovered.

The dynamic holdup in the column varied from 25 to 35 ml. Therefore, it was not possible to determine the end point temperatures. The maximum pot temperature was 750 F or cracking temperature.

Engler Type Vacuum Distillation. The procedure followed in the vacuum Engler type distillation was that specified in ASTM Distillation Method D 1160-52T.[1] Operating pressures were 760, 400, 200, 100, and 50 mm Hg. With certain of the heavy stocks the distillate rate was reduced to 1 ml per minute.

Results

Data obtained from the distillation of the 29 petroleum stocks studied are contained in Table 1.

The estimated possible limits of error in the operational procedure and measurement reflected in terms of temperature are shown in Table 2.

All samples were re-checked if when plotted the points did not fall on a smooth continuous curve. The estimated possible error is somewhat greater than that normally allowed for ASTM distillations. Under 50 mm Hg absolute pressure a fluctuation in pressure of 1 mm can cause a temperature fluctuation of approximately 2 F. Also variation in ambient air current caused some fluctuation in readings.

TABLE 2. Estimated error in temperature readings.

	TBP 50 mm	ASTM 760 mm	Engler 400-50 mm
Initial F	±5	±5	±5-6
End point F	—	±3	±5
Intermediate F	—	±2.5	±3.5
Cut volumes, ml	±2	—	—

For some of the heavy stocks there was a tendency for some flashing at the lower pressures at the specified distillation rates. This necessitated reducing the distillation rate to around 1 ml per minute at 50 mm. The possible effect of the reduction in product rate would be to increase the reflux in the neck of the flask and therefore increase the slope of the distillation curve.

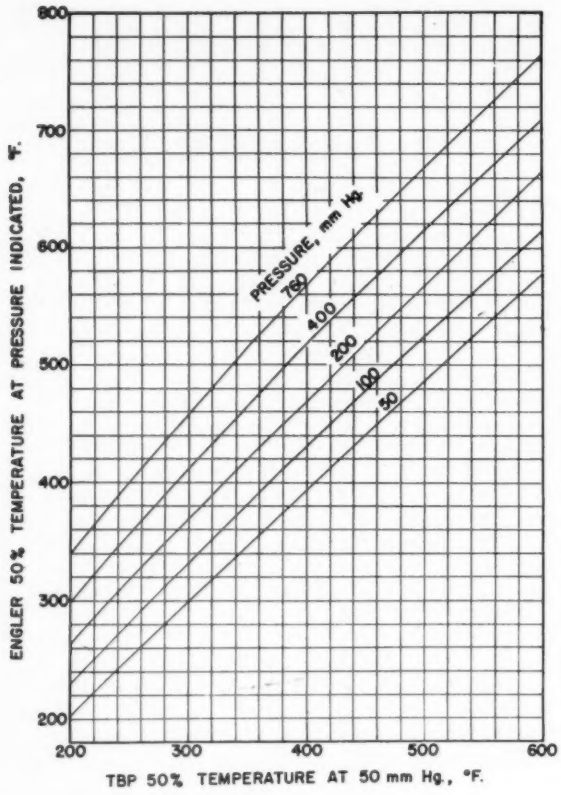

FIG. 1. Correlation of TBP vs Engler 50% temperatures.

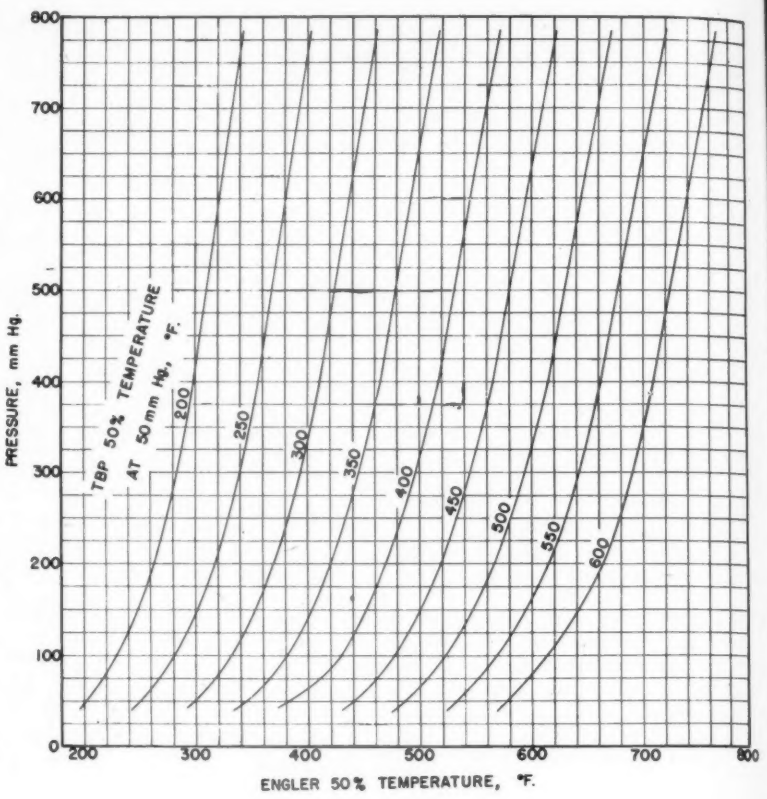

FIG. 2. Correlation of Engler 50% temperature vs pressure.

Quantitative evaluation of this effect was impossible to determine.

Correlation

It was first attempted to determine the effect of pressure on the 10-70 per cent slope of the Engler type distillation curves. After they were calculated, it was evident that little or no change in slope with reduced pressure resulted from the data obtained in this investigation.

Okamoto and Van Winkle[3] found that the TBP slope decreases with decrease in pressure and Edmister[2] and Okamoto and Van Winkle[4] found the flash slope to increase with decrease in pressure. As the Engler type distillation represents a distillation conducted under conditions intermediate to these, but having little reflux, the slopes of the curves were thought to increase with decrease in pressure. Therefore, the results developed here might be subject to some question. It is doubtful, however, that the possible effects of temperature fluctuation and reduced distillate rate could obscure any significant change in slope caused by pressure.

Although the slope of the Engler type distillation curves did not change significantly with reduction in pressure, the correlation represented in Fig. 1 was devised. This relates the 50 TBM temperature, F at 50 mm Hg pressure with the 50 per cent Engler type distillation temperature F with parameters of constant pressure (for the Engler type distillation curve). Mean deviation of the 5 pressure parameters ranged from ± 2 deg to ± 4 deg.

Use of Correlation. When the evaluation of crude oils, reduced crudes, or heavy oil fractions is carried out in the laboratory using a vacuum Engler type or ASTM vacuum distillation, the atmospheric Engler type or ASTM curve can be derived as follows: As the point corresponding to the Engler or ASTM vacuum distillation 50 per cent temperature read the corresponding TBP 50 per cent temperature at 50 mm on the line corresponding to the pressure of the distillation. Move along the vertical line corresponding to this TBP 50 mm 50 per cent temperature to the 760 mm curve. Read the 50 per cent ASTM temperature on the ordinate.

Determine the temperature difference between the vacuum ASTM or Engler distillation 50 per cent temperature and the 760 mm ASTM or Engler 50 per cent temperature. Add this difference to each icremental 10 per cent temperature of the vacuum ASTM or Engler curve to evaluate the entire 760 mm curve. This is a valid calculation as the slopes are shown to be essentially the same.

The atmospheric TBP curve can be constructed from the ASTM or Engler type vacuum distillation by determining the atmospheric ASTM or Engler distillation curve as above and using existing correlations between 50 per cent temperature and slopes of the flash, ASTM, and TBP distillation curves.

(Complete data developed in this investigation are available in the M S Ch E Thesis by H. A. Oehler, "Correlation of TBP and ASTM Type Distillations at Subatmospheric Pressures" (1954) University of Texas Library.)

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Cooling Tower Wood Can Be Protected

Chemical and bacteriological attack can be controlled by acid treatment and wood preservatives to kill fungi

RICHARD B. CONLAN*

IN recent years deterioration of cooling tower wood has been recognized as a problem of increasing importance. The attack may be chemical or biological in nature. This problem is of particular interest to the petroleum industry because of the larger number of cooling towers in use.

Because it is a durable material, wood is most commonly used in cooling tower construction. California Redwood, Cypress, and Yellow Pine are generally used in such construction although Douglas Fir, White Oak, and Southern Pine may also be employed. Chemically, wood consists of carbohydrates (largely cellulose), lignin and extraneous matter. More than half the dry weight of the wood is due to the cellulose while the lignin comprises somewhat less than one-third the weight. Extraneous matter or extractives are present in cell cavities in quantities as high as 30 per cent of the dry weight of the wood. These extractives contain constituents that are toxic to wood-destroying organisms.

While the tower is in operation, the wood is subjected to varying moisture conditions in an atmosphere of warm and humid air. Some sections of the tower are constantly in contact with the flow of cooling water and other sections are continually bathed in a mist. In some locations of the tower the wood is intermittently splashed or flooded while in other sections the lumber is submerged at all times. Premature deterioration of the cooling tower lumber may occur under these extreme conditions of operation.

Chemical Attack and Its Control

Chemical attack of cooling tower lumber has long been recognized as a serious problem in cooling tower maintenance. The surface of the affected wood shows various physical appearances, depending upon the particular chemical agent or agents responsible for the attack. The cause of the condition must be identified and the proper corrective measures must be taken to control the problem.

Chemical Attack. This type of attack may take place in areas where the cooling tower lumber is continually wetted while the unit is in operation. It may also occur where intermittent wetting takes place. The most common type of chemical attack involves removal of the lignin binder from the cellulose fibers. This is generally referred to as delignification. Selective removal of polysaccharides, especially cellulose, may also occur. It has been shown by investigators that this condition occurs in the presence of high concentrations of sodium carbonate in the circulating water. Sodium carbonate may be naturally present in the makeup water or may be present due to lime — soda ash softening or sodium zeolite softening of the makeup water. Sodium zeolite softening converts calcium and magnesium bicarbonate to sodium bicarbonate which, on concentration in the tower system, will partially decompose to sodium carbonate in the circulating water. Some investigators have indicated that the presence of either sodium carbonate or sodium bicarbonate is about equally effective in producing this type of deterioration.

The effect of sodium carbonate solutions on woods generally used in cooling tower construction has been shown by laboratory experiments. Fig. 1 shows that a straight line relationship exists between weight loss and sodium carbonate concentrations in the range of 1000 to 36,000 ppm and this effect is independent of the pH value. In the laboratory experiments that were conducted weighed samples of dry wood were immersed for 60 days in sodium carbonate solutions ranging in concentration from 1000 to 36,000 ppm. When removed, specimens were washed in distilled water and washings returned to original solutions. After drying the specimens were reweighed and solutions were analyzed for total extract content. Test results indicated that the weights of the extracts equalled the loss in weight of the specimens, within the limits of the test. Similar experiments were conducted employing high concentrations of neutral salts, in-

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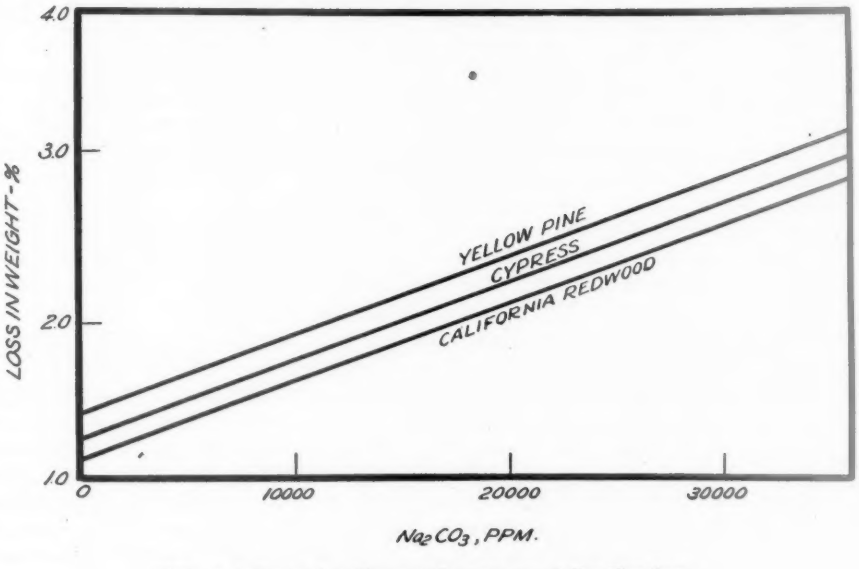

FIG. 1. Effect of sodium carbonate on delignification.

*W. H. and L. D. Betz, Consulting Engineers.

cluding sodium chloride, sodium sulfate, calcium sulfate, and magnesium sulfate. Results of these tests indicated little difficulty was encountered when the pH was between 7.0 and 7.5.

The pH value of the circulating water cannot be used directly as a measure of the tendency toward delignification. For example, it is possible to store 3 per cent caustic soda solutions (pH range 13.0-14.0) in Redwood tanks without any noticeable deterioration. Concentrated solutions of sodium carbonate, on the other hand, cannot be stored satisfactorily in Redwood tanks without noticeable deterioration, even though the pH does not exceed approximately 11.5.

Wood may be destroyed by a number of chemicals such as those used in pulping where strong solutions are used in conjunction with heat and pressure. Both sodium carbonate and sodium bicarbonate are listed as pulping agents although neither is used in commercial wood pulping since these agents also remove the hemi-cellulose and degrade the alpha-cellulose components. Thus, in delignification, not only is the lignin removed, but tannin and other extractives are also removed.

In flooded portions of the tower chemical deterioration, identified as delignification, will show a general reduction in cross-sectional area of the affected lumber. This type of chemical attack is characterized by the presence of a mat of white fibers on the wood surface. Fibers may be loosely attached or tightly compressed to the surface of the wood. This condition should not be confused with the presence of thin scales of soluble salts, which often produce a white color on the surface of the wood.

Fig. 2 illustrates a slat section removed from an atmospheric cooling tower in the Southwest and shows the characteristic appearance of delignification. At this particular plant the pH of the circulating water was often as high as 9.9 to 10.1 with phenolphthalein and methyl orange alkalinities respectively as high as 760 ppm and 2480 ppm as calcium carbonate. Chemical analysis of such specimens shows that the lignin is reduced to a greater extent than any other component of the wood. The extractive content is reduced to a lesser extent than lignin but to a greater extent than cellulose.

Cooling tower lumber may also deteriorate under acidic conditions. Although wood is slightly acidic in nature, appreciable attack occurs at pH values below 5.0. Such conditions have been noted where the cooling tower lumber is in contact with acid fumes and under this condition the attack is principally on the cellulose content. The surface of wood so attacked is broken down and shows numerous long reddish-brown fibers.

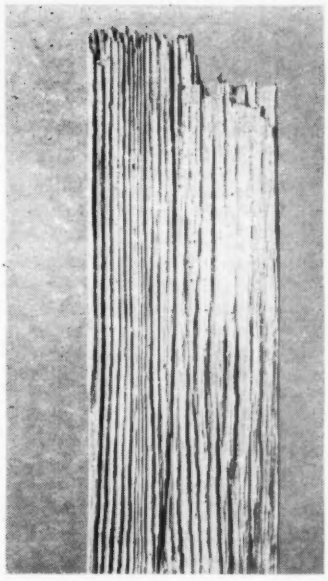

FIG. 2. Delignification of slat section from atmospheric cooling tower.

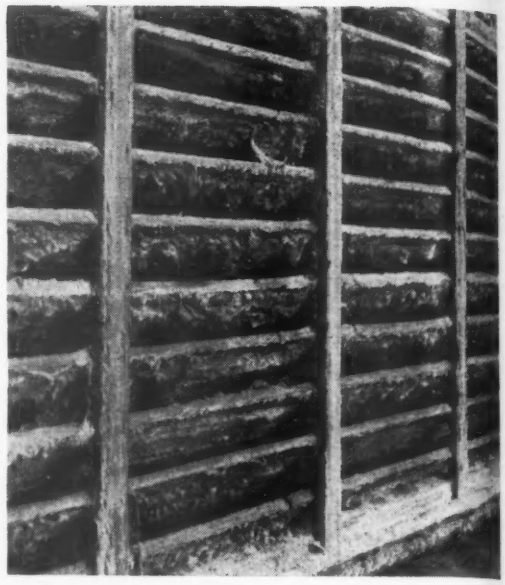

FIG. 3. Salt deposit on tower section resulting from total evaporation.

As lignin may be removed selectively by oxidizing agents, excessive quantities of chlorine, used for the control of slime and algae growths, should be avoided. Chlorine is known to attack all constituents of the wood, including the toxic extractives, although lignin and hemi-cellulose are most susceptible. It is important to note that removal of the toxic extractives lowers resistance of the wood to biological attack. A chlorine residual in the range of 0.5-1.0 ppm should be sufficient to control slime and algae growths without appreciable attack on the cooling tower lumber.

Very rapid lignin removal occurs when wood is subjected to alternate treatment of highly alkaline solutions and oxidizing agents. However, in circulating cooling water systems the water would not normally be considered highly alkaline. Also, if chlorine were employed, this oxidizing agent would not normally be present in sufficient quantity to promote rapid lignin removal. However, over an extended period of time deterioration of lumber has occurred where the circulating water pH is high. This condition of deterioration is produced rapidly by increasing the chlorine residual. Where chlorine residuals above 1.0 ppm are maintained in circulating waters of high pH value, a severe condition of deterioration occurs.

The distribution of water over the tower is another factor influencing chemical deterioration. Intermittent splashing on some parts of the tower, such as the louvres, permits salts to concentrate sufficiently by evaporation. Fig. 3 illustrates the condition that results from total evaporation of salts. At wetted and dried areas of the tower there is a tendency for the saturated water to be absorbed by the wood. The formation of crystals beneath the surface mechanically disintegrates the wood. Alternate wetting and drying of these areas will cause further rupture of the cell membranes, continually exposing fresh surfaces to attack. Wood subjected to such attack shows soft loose fibers and is greatly reduced in strength qualities.

Control of Chemical Attack. Several factors are involved in the prevention of chemical attack on wood. These include the total alkalinity and the pH value of the water as well as the dissolved solids concentration. The pH value alone cannot be used as a control factor since a high bicarbonate content of the circulating water will have somewhat the same effect as a high carbonate concentration. By limiting cycles of concentration, it is possible under certain circumstances to control both pH and alkalinity to within tolerable limits. This type of control is usually not practical for makeup water of appreciable alkalinity content. Acid treatment of circulating water is generally used for control of both pH and alkalinity.

For prevention of scale formation and for maintenance of an economical blowdown rate, acid treatment of the circulating water is usually desirable. Acid treatment is also of considerable value in providing the optimum pH for control of pitting and tuberculation. The Dianodic method of inhibiting pitting and tuberculation relies on adjustment of pH, together with the feed of phosphate and chromate at specified ratios, to control pitting at economically low treatment concentrations.

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FIG. 3059G—300-Pound Steel Flanged End Valve. Sizes 6" to 12".

FIG. 1559—150-Pound Steel Flanged End Valve. Sizes 1" to 4".

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Figs. 4 and 5 illustrate research data on the reduction in pitting secured with the Dianodic method as compared with the separate use of phosphate and chromate. As can be noted, at a pH of 6.5, which is quite favorable in preventing attack on wood, the Dianodic method provides marked inhibition of the pitting effect.

Extremely high concentrations of dissolved solids in the circulating water should be avoided where there is a possibility of alternate wetting and drying of certain areas of the tower. Although neutral salts possess little tendency to attack wood, crystallization of these salts in wetted and dried areas may rupture the wood cells. The salts may be removed by periodic hosing down of these sections of the tower. Where rupture of wood cells cannot be controlled in this manner, additional blowdown will serve to lower the solids content of the circulating water and assist in the control of this problem.

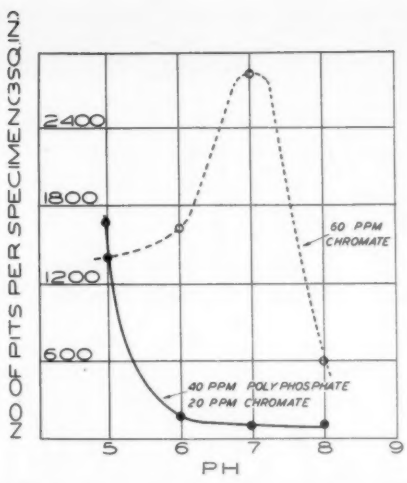


FIG. 4. Reduction in pitting by Dianodic method vs. phosphate at various pH values.

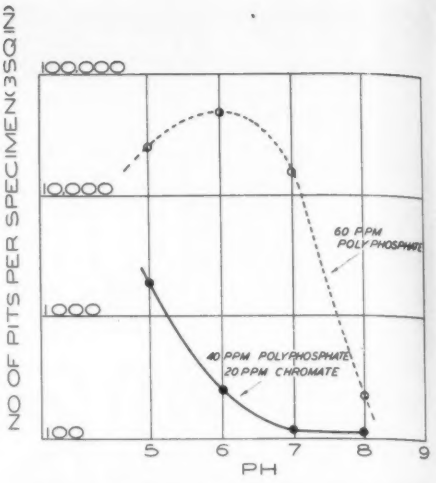


FIG. 5. Reduction in pitting by Dianodic method vs. chromate at various pH values.

Biological Attack and Its Control

Although biological attack has only recently been recognized as such, there is no doubt that this type of deterioration has been responsible for the destruction of a considerable amount of cooling tower lumber. Prior to the time this form of attack was recognized, much of the destruction for which it was responsible was probably attributed to chemical attack or was not reported.

Biological Attack. Biological attack or decay of cooling tower lumber is caused by the presence of microorganisms that utilize the wood for food. The true wood-destroying fungi utilize either cellulose or lignin for food while some species of fungi live wholly on certain sugars and extractives. The durable woods, such as Redwood, contain toxic extractives that prevent the growth of organisms. Growth of fungi does not occur in the absence of oxygen. The cell wall of the wood must be saturated with moisture and an excess of moisture must be present in the cell cavities. Dry wood does not decay and water-logged or submerged wood is not attacked by fungi since oxygen is excluded.

Fungi belongs to a class of the vegetable kingdom and differ most from other plants in that they do not produce chlorophyll. They are unable, therefore, to build up their food material by the action of sunlight on carbon dioxide and water. Nourishment is derived from organic materials.

The fungi are filamentous in nature and though they may form quite large growths these are formed by interweaving of masses of extremely fine fungal threads (Hyphae). Fungi are reproduced by means of spores and these may be single celled or multi-cellular. The spores are normally air-borne and germinate after lighting on the surface of the wood, under favorable conditions. The vegetable part of the fungus (Hyphae) penetrates the wood while the fruiting body of the fungus (sporophore) develops on the surface of the wood.

The wood-destroying fungi are rather tolerable to variations in both pH and temperature. It appears, however, that pH values slightly below 7.0 are optimum for growth. The attack of fungi appears most severe when the temperature within the wood is between 88 F and 105 F. On freezing the fungi become dormant while a temperature of 150 F for a period of 30 min is required for killing.

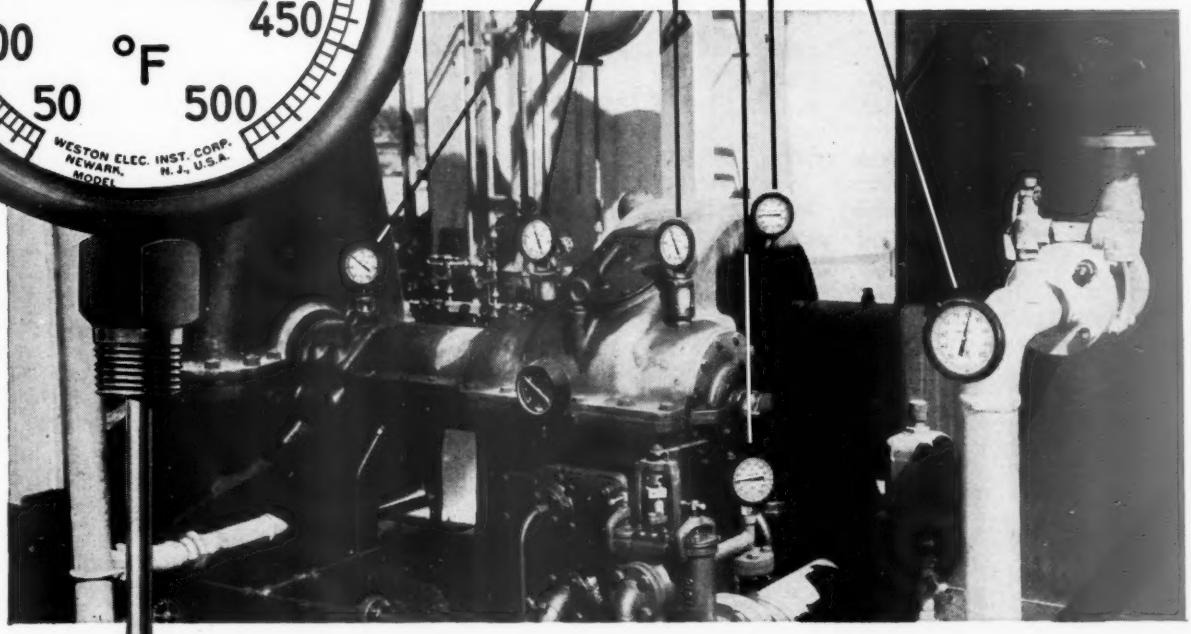
Biological attack is not confined to any particular section of the cooling tower or to any particular type or make of tower. The growth of wood-destroying fungi seems to be most noticeable in the mist sections of the tower, such as at the eliminators or beyond the eliminators. In such sections the wood that has been attacked may appear normal on the surface although decay has occurred below the surface. Fig. 6 illustrates fungus attack on a slat section from a refinery cooling tower. As can be noted, the exterior of the slat shows normal characteristics, but when broken open the interior reveals extensive attack by wood-destroying fungi. In the initial stages of such decay the interior of the affected wood is often delaminated. As attack progresses this interior takes on a soft punky condition. Chemical analysis of wood showing this internal biological attack indicates that a selective removal of cellulose has occurred.

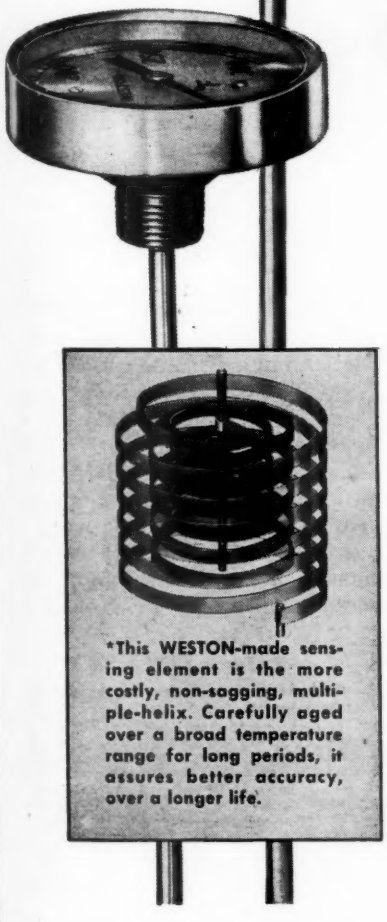
In other sections of the tower, such as where the lumber is flooded during operation, the deterioration occurs principally on the surface of the lumber. Previously this type of decay had been considered to be the result of chemical deterioration. It is probable that this biological surface decay is preceded by chemical attack. A chemical analysis of wood showing biological surface attack normally indicates selective removal of cellulose and a reduction in extractive content to approximately the same level as occurs during chemical attack.

As biological surface deterioration closely resembles chemical attack in appearance, a mycological examination is necessary to determine if wood-destroying organisms are present. It is rarely possible to determine the amount of deterioration due to biological attack and that due to chemical attack. Bio-

FIG. 6. Fungus attack on salt section from refinery cooling tower.

AT EVERY CHECKPOINT





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logical attack is similar to chemical attack in that it produces a condition of brittleness due to loss of strength. This condition is referred to as brashness and may be identified by breaking a section of infected wood and noting the fracture. Normal wood breaks with a series of fractures across the grain together with splitting along the grain. Brash wood does not split but fails with a single break square across the grain.

It is not possible to predict attack on cooling tower lumber by wood-destroying organisms. Conditions that are favorable to chemical attack, however, seem to increase the possibility of biological attack. Surveys have shown that biological attack seems to be more prevalent in towers operating with water of relatively high pH value. This would indicate that high alkalinity circulating waters tend to accelerate or encourage leaching of the natural toxic extractives, thus lowering the normal resistance of the wood to decay.

Control of Biological Attack. Although control of alkalinity, pH, and solids content of the circulating water can prevent chemical attack, it will not prevent biological attack but will serve to minimize the possibility of biological infection. Where attack has occurred, and this attack is not the result of chemical deterioration, it is desirable to conduct a mycological examination on the affected wood. The tower lumber should be inspected periodically and any infected lumber should be replaced as soon as it is discovered.

For many years wood preservatives have been employed to protect wood from decay when it is used in such applications as railroad ties, fence posts, telephone, and power line poles. As biological attack of cooling tower lumber has been recognized only recently, there is little data available on the effect of wood preservatives in resisting this type of attack. Some tests are now in progress, however, on the applicability of wood preservatives for cooling tower lumber.

Many chemical agents have been employed as wood preservatives in fields other than the protection of cooling tower lumber. Fig. 7 gives a list of chemical preservatives and their toxicity to a certain wood-destroying fungus. Toxicity data on a certain organism will not necessarily apply to other species and, it must be understood that there are a large number of wood-destroying fungi.

One fact discouraging possible use of wood preservatives for impregnating cooling tower lumber is the effect the circulating water would exert in leaching water soluble preservatives from the wood. The Forest Products Laboratory has developed the double-diffusion method of impregnating lumber which consists in soaking the wood first in one chemical solution and then in a second chemical solution. The two solutions diffuse into the wood and react, in the wood, to form an insoluble precipitate that is toxic to fungi. Copper sulfate, followed by sodium chromate has given excellent results where this method has been used in test stakes. Other solutions employed have been copper sulfate and arsenic acid, followed by sodium chromate. Zinc sulfate and arsenic acid, followed by sodium chromate, also shows some promise.

Copper pentachlorophenate is an excellent wood preservative and concentrations as low as 5 ppm have inhibited the growth of Lentinus lepideus, Lenzites sepiaria and Fomes pini. Because of the isolubility of copper pentachlorophenate in water, special methods of solubilizing this material are necessary.

FIG. 7. Toxic concentrations of various chemicals to the fungus "Madison No. 517"*

Chemical	Formula	Toxic concentration, ppm
Boric acid	H_3BO_3	2500
Coal, tar, creosote	...	500-10,000
Copper arsenate	$Cu_3(AsO_4)_2 \cdot 4H_2O$	500
Copper pentachlorphenate	$Cu(C_6Cl_5O)_2$	20
Mercuric chloride	$HgCl_2$	60
Orthochlorophenol	C_6H_4ClOH	400
Phenol	C_6H_5OH	2000
Pentachlorophenol	C_6Cl_5OH	20
Silver nitrate	$AgNO_3$	300
Sodium chromate	Na_2CrO_4	340
Sodium fluoride	NaF	2500
Sodium hydroxide	NaOH	3000
Sodium pentachlorphenate	C_6Cl_5ONa	20
Sulfuric acid	H_2SO_4	1500
Zinc sulfate	$ZnSO_4 \cdot 7H_2O$	6500
Zinc meta arsenite	$Zn(AsO_2)_2$	1000

* From "Wood Preservation," 2nd Ed. by G. M. Hunt and G. A. Garrett, McGraw Hill Book Co., New York, N. Y., (1953).

As considerable time will be required to prove the worth of wood preservatives for cooling tower lumber, and as existing cooling towers must be protected, present research is being directed toward control of wood-destroying fungi by treatment of the circulating cooling water. Chemical agents most applicable to this problem include copper sulfate, sodium pentachlorophenate, zinc sulfate, and sodium chromate along with other preservatives. Various methods may be used to apply the chemical toxicant. A concentrated solution of the toxic material may be sprayed directly on the affected wood. The preservative may also be sprayed into the tower, after draining, with the fans on to distribute the chemicals.

It is recommended that the entire at periodic intervals, similar to the method used for the control of slime and algae.

Conclusions

Chemical attack of cooling tower lumber is more common than bacteriological attack. Chemical attack may occur due to high sodium carbonate content of the circulating water. The presence of high alkalinity in the circulating water and high concentrations of an oxidizing agent, such as chlorine, tend to increase the rapidity of chemical attack.

Chemical attack on cooling tower wood can be controlled by acid treatment of the circulating water. Although a pH value of 6.5 is most desirable for prevention of attack, pH is not the sole factor involved. Total alkalinity must be controlled to a reasonable level.

Preventive maintenance in hosing down sections of the tower, where salts have deposited from total evaporation, will aid greatly in preventing chemical attack at these points. Since chemical attack of cooling tower lumber is usually evident from visual inspection, a regular procedure should be established for making periodic inspections of the tower.

Decay of cooling tower lumber has been found in only a small percentage of the total number of towers in operation. Fungus attack manifests itself in the form of both a surface attack and an internal biological attack. Since chemical attack lowers the normal resistance of the wood to biological attack, proper steps should be taken to prevent chemical attack and thereby minimize the possibility of biological infection.

Studies are presently being conducted on the effect of wood preservatives for cooling tower lumber. The control measures presently available for protection of existing cooling towers rely on precipitation within the wood of insoluble toxic agents, resistant to leaching. Because of the expense involved, it is questionable if such treatment should be applied as a preventive measure, particularly when these materials are not regularly employed in the slime and algae control program. It may be advisable to consider such treatment only after a tower examination has indicated one of the infrequent instances of biological attack.

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Editorial Review, Power, 98, 113-117, (Feb. 1954).

* * *

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T. B. Rendel, left, special assistant on aviation, etc., to the refining vice president of Shell Oil Company, New York, talks over matters with Lee Oldfield, well known automotive consultant.

W. P. Murphy, left, Lubrizol Corporation, "tells a funny one" to William Power of Cities Service Oil Company. Nearly 500 engineers attended the SAE meeting.

New Engine Designs, Fuel Needs Hold Attention of Automotive Engineers

ARCH L. FOSTER*

IN its largest meeting to date (nearly 500 engineers attended the sessions) the Fuels and Lubricants Activity of the Society of Automotive Engineers studied and discussed most of the major phases of its multitudinous problems during its three-day meet in Tulsa, Oklahoma. Out of the papers and discussions presented there a long list of important facts came to light, affecting seriously the operation and the salient developments in automotive engineering and petroleum refining for 1954.

In the study of nine models of 1954 passenger cars that have brought out significant new engine design and showing data collected from 235 cars, six models of which had been tested in previous surveys, five of these six models displayed a need for motor fuels having 2 to 6 octane numbers higher than was needed by the same models with the earlier engine designs. Eighty-six to 94 research octane number fuels were needed to satisfy the knock tendencies of 50 per cent of the cars in the nine models. Research ratings ranging from 90 to 96 octane number were needed to satisfy 90 per cent of the cars in this group. Part throttle operation called for the maximum octane number fuel in 95 per cent of the cars of one model; in the other models maximum octane needs at part throttle were called for in percentages ranging from none to 64 per cent. Average difference in required ratings between part and full throttle ranged from 0.5 to 5 octane numbers. Interestingly enough, 32 cars, tested under hill-climbing conditions, showed a need for 2.4 octane numbers higher fuel than for level-road operation.

Nitromethane dissolved in either alcohol or hydrocarbons can be used to boost the power output of a unit by as much as 18 per cent, brake basis, or 13 per cent, indicated basis, it has been found. The limiting factor is the introduction of pre-ignition. Increased fuel consumption always follows this use of nitromethane, along with a higher thermal efficiency. Nitromethane is employed in, for example, racing fuels where the ultimate inpower output far overshadows any consumption or cost considerations.

Diesel Fuel Problem

Hammering away at the problem of diesel fuels and the effects of their use on engine operation, it is found that ring-groove deposits increase as fuel sulfur content increases; this effect varies with different engines, and also decreases as engine load is increased.

At 100 per cent load, deposits rose 20 per cent when 1 per cent more sulfur was present in the fuel. This ratio varied widely in different engines. Exhaust deposits also increase with load, also with sulfur content, although at 100 per cent load they were still too small to be significant.

Ring wear usually doubled when sulfur was increased from 0.25 per cent to 1.25 per cent; one engine multiplied its ring wear five-fold with this change in sulfur content. Presence of aromatics in the fuel increased ring deposits only slightly; ring wear was affected almost not at all by aromatics. Raising aromatics from 14 to 45 per cent raised exhaust deposits by 101 per cent. The 0.25 per cent to 1.25 per cent sulfur boost raised deposits and wear 135 per cent. Wear is more sensitive to sulfur content than to aromatics content or to average boiling point changes.

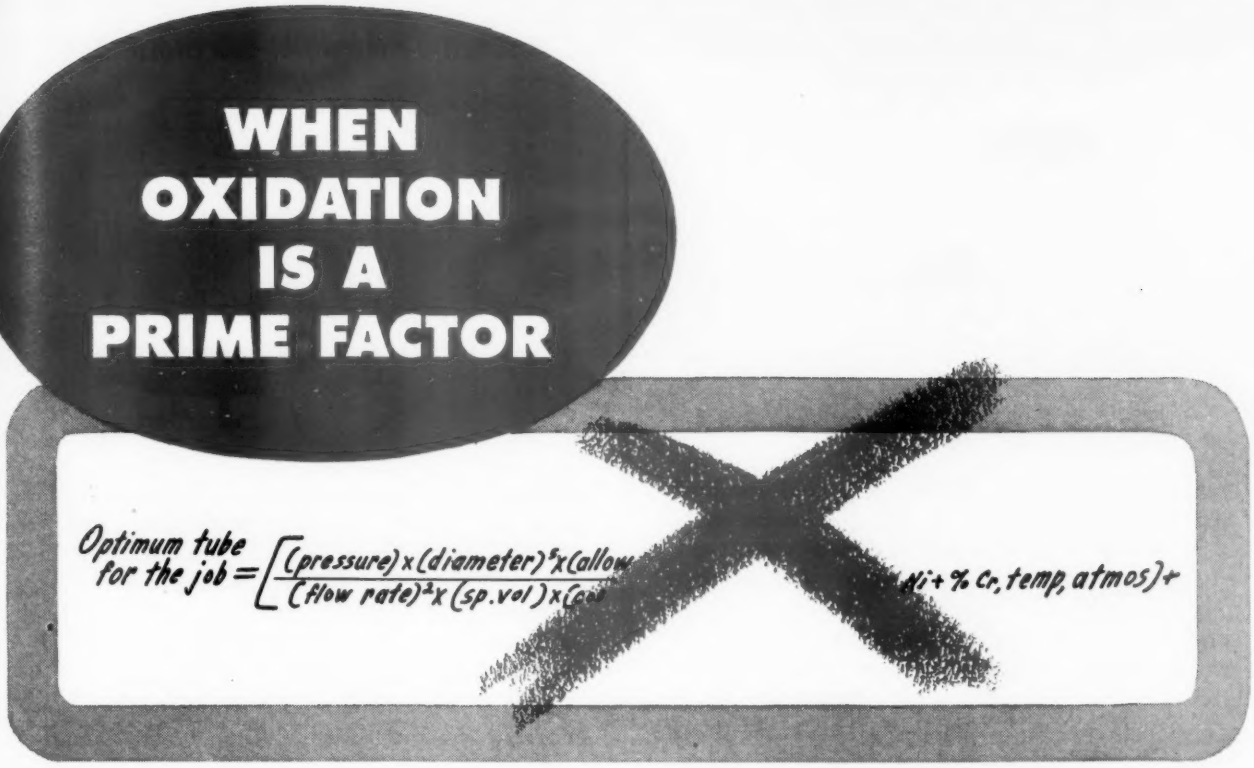
LP-Gas as Bus Fuel

In the use of LP-Gas as bus fuels, in city bus operations, the presence of as much as 15 per cent of the olefin, propylene, will be as satisfactory as operation on regular natural gas LPG without any olefins present, it has been found. Engines operated on propylene-

William H. Little, veteran of trade journal publishing, and Robert J. Mahaffay, both of Chek-Chart Corporation, talk shop at the Tulsa SAE meet.

*Editor, Refining and Petrochemicals edition.

WHEN OXIDATION IS A PRIME FACTOR



Tube Selection Cannot be Reduced to a Formula

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When any metal is exposed to high temperatures, it burns. Slow burning is called oxidation and in the process scale forms on the metal being burned. If the process continues the scale will flake off, causing loss of metal.

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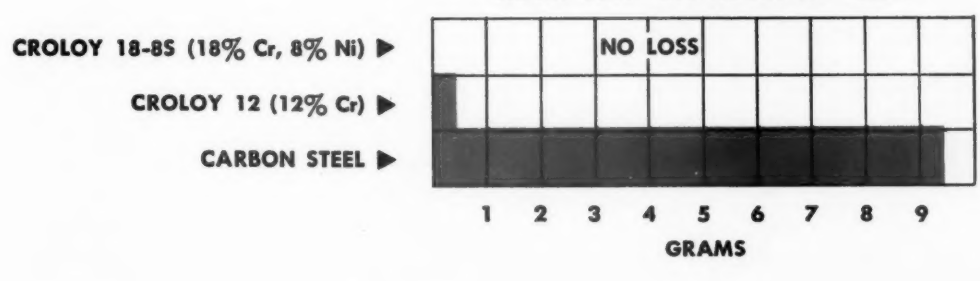

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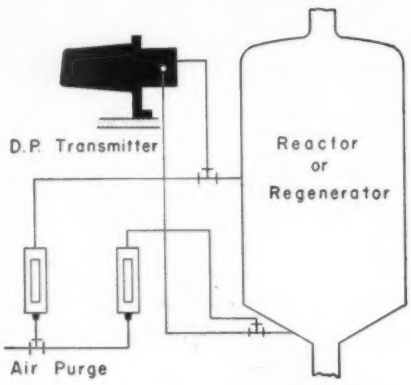
CATALYST LEVEL



Problem: Sensitive Level Measurement of fluid catalyst in Reactor or Regenerator requiring a range of approximately 600 inches of water, and with a unit having parts common to other process measuring elements.

Solution: Use of a 333RD force-balance differential pressure transmitter with an available range adjustment of 80 to 800 inches of water.

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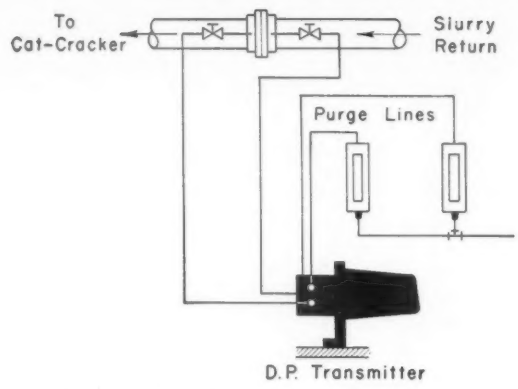
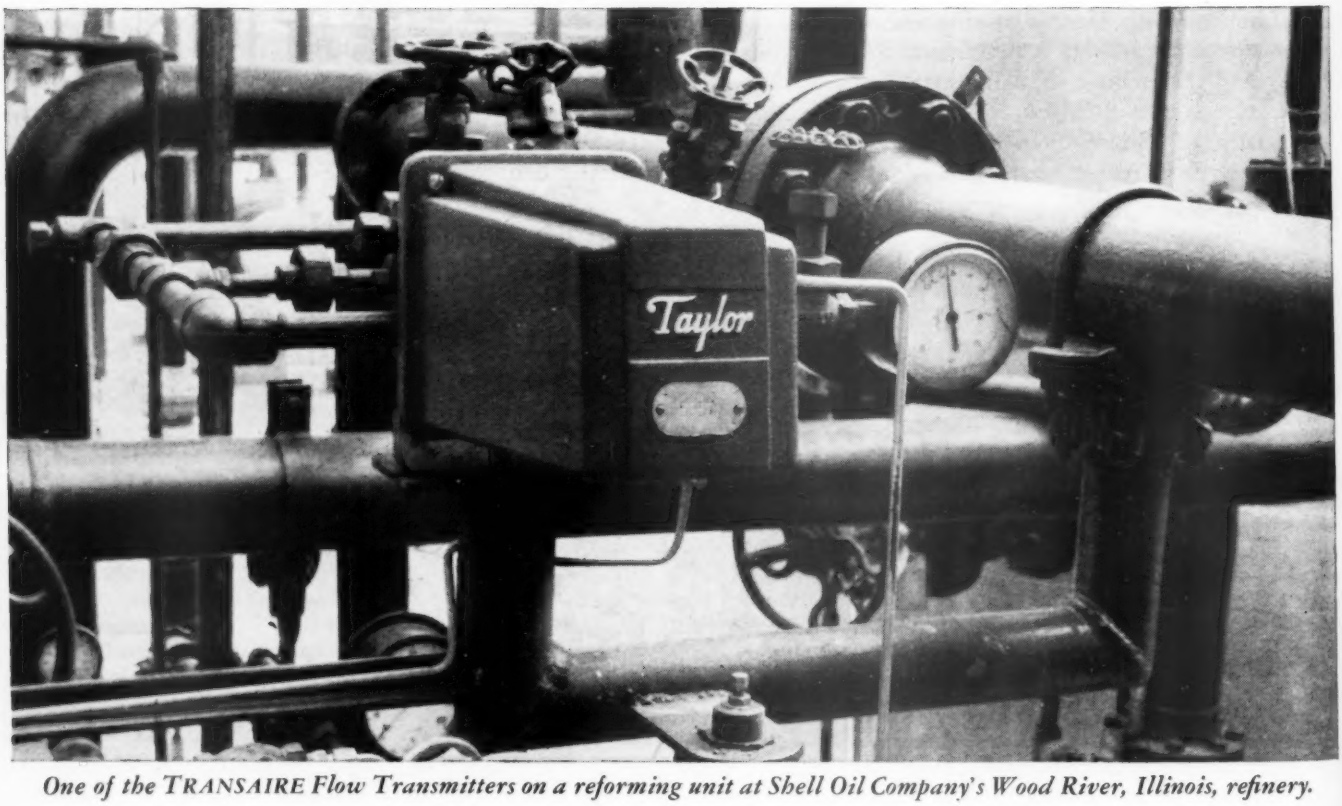


Problem: To obtain uninterrupted flow measurement and control in slurry lines where catalyst solids in suspension can settle out, plugging lead lines and meter, and causing measurement errors.

Solution: Dual body taps provide for purge connections which keep 333RD body, as well as lead lines, completely flushed.

Result: Consistent, dependable high measurement accuracy. Flushing of transmitter body as well as lead lines cuts maintenance to a minimum, especially after shutdown.

A SIMPLE ANSWER TO



One of the TRANSAIRE Flow Transmitters on a reforming unit at Shell Oil Company's Wood River, Illinois, refinery.

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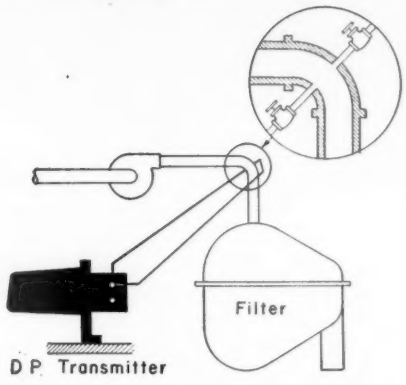
SHORT RUNS—REVERSE FLOW—VARYING VISCOSITY



Problem: Dependable flow measurement installation where piping runs are too short for accurate orifice plate installation, the flow is reversed and/or flowing liquid has a varying viscosity.

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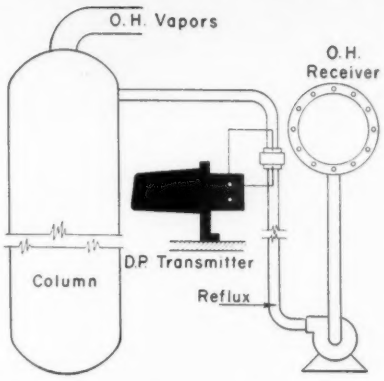

Problem: To improve flexibility, as well as reduce installation and maintenance costs of conventional flow instruments.

Solution: Standardizing on the 333RD Transmitter. 10-to-1 quick and easy range change; minimum volumetric displacement; may be installed for continuous draining and venting; light weight.

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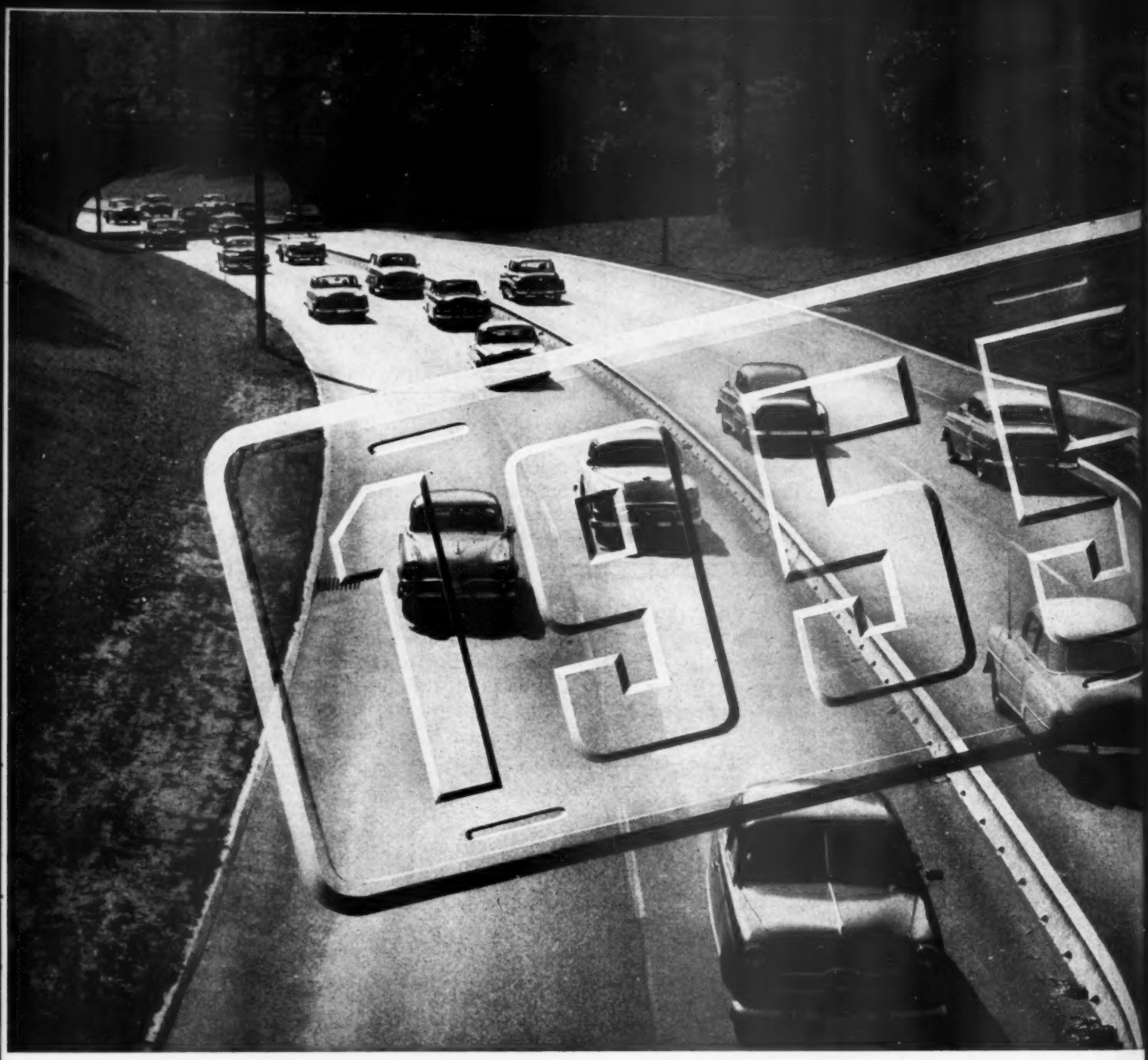

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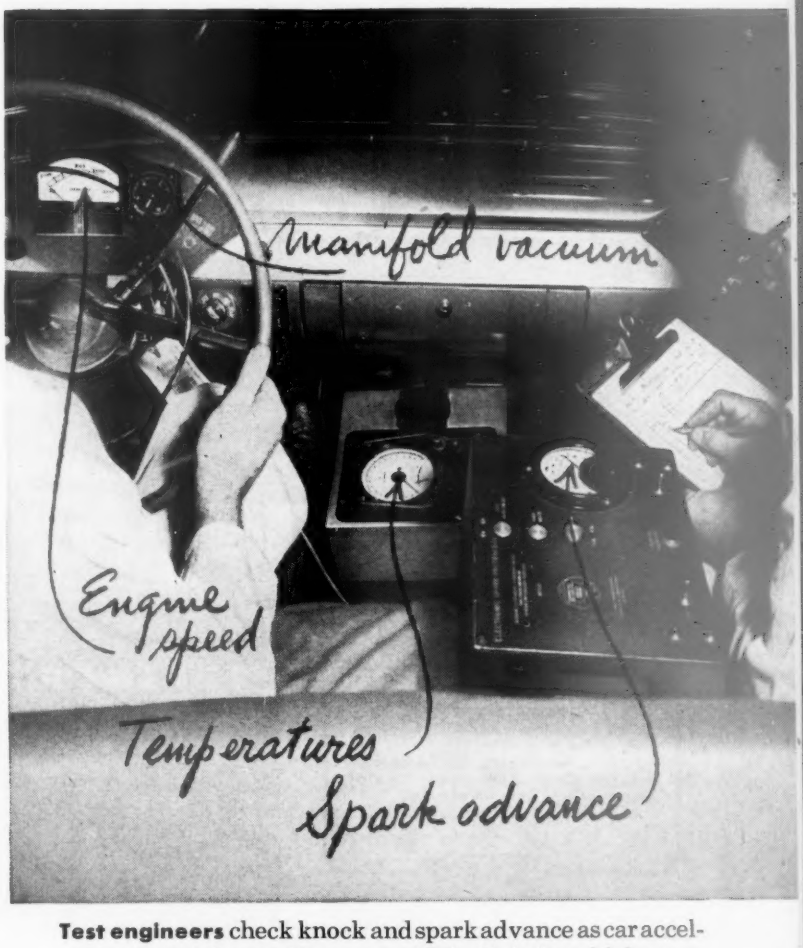

Test engineers check knock and spark advance as car accelerates to "high speed" on one of Ethyl's indoor highways.

butane-propane remained as clean as those using natural gas—butane-propane—fuels without olefins. No harmful effects on the test coaches were found, as to increased deposits, either.

The most effective and economical solution of the carburetor gumming problem is the use of detergent-action gasolines that remove gum deposits during normal engine operaton. Carburetor gumming results from contaminants in the inlet air, especially when the engine is idling. Results of standard gasoline gum tests do not enable us to predict carburetor gumming tendency. Greatest source of inlet air contamination is blowby fumes, with half the gum found being traceable to this one factor. Other vehicles' exhausts, smoke, and dust are lesser culprits.

In testing inlet system deposits by means of alumina-packed adsorber columns for concentrating deposit precursors, it has been found that non-hydrocarbons are responsible largely for most of this deposit problem. These non-hydrocarbons are adsorbed strongly on alumina; they show an especially strong resistance to being desorbed by benzene, which is the hydrocarbon component normally found in gasolines that shows the strongest adsorption tendency of alumina. The alumina concentrates especially compounds containing oxygen, nitrogen, and sulfur. Phenols, such as cresols, do not induce or form deposits but thiophenol, sulfur analog of cresol, is very detrimental. Strangely enough, the aliphatic mercaptan n-butanethiol was shown to be harmless in forming intake deposits.

Modernized Lubricants

Operating "20 mm bore tool steel ball bearings" at 2500 rpm and elevated temperatures has disclosed that a graphite-air mist lubricates these units at 1000 F; a molybdenum disulfide-air mist works properly up to 850 F, and a synthetic diester served satisfactorily up to 700 F. The disulfide continued to lubricate the bearing up to 1000 F but did not give entirely satisfactory results as did the graphite-air mist above 850 F. Solid lubricants proved better at the very high temperature ranges than any liquids studied. Syrup-bonded molybdenum disulfide coatings were not effective in lubricating cylindrical roller bearings.

Contrary to earlier accepted ideas, some recent results indicate that increased wear of engine pistons, rings, and cylinders is related directly to lower oil consumption, and that increasing oil consumption may reduce wear. "The magnitude of the differences," says A. M. Brenneke and M. E. Estey of Perfect Circle Corporation, "is such that the matter is of more academic than practical importance." Use of 5/64-in. width compression rings as of nowadays increases wear over that found with the older 3/32-in. wide rings. Comparison cooling characteristics of old and new design engines makes it appear that the emphasis by the petroleum industry on corrosive wear is both timely and sound.

Correlate Use with Properties of Products

The summation of the innumerable ideas brought out in this meeting emphasizes the fundamental principle that the best methods for determining the properties of petroleum products should be correlated with the requirements of the automotive equipment in which they are used. Even more fundamental is the principle that design of automotive equipment must be governed by the optimum properties obtainable in the petroleum industry products for the consuming public as automotive equipment operators. Also, the economics of engine operation is a subject of increasing importance, all too often relegated to a poor second place in favor of that "flashing performance" expression. * * *

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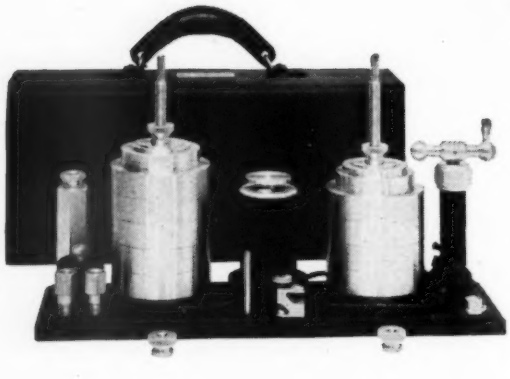

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LP-Gas Sales Exceed Five Billion Gallons

GEORGE R. BENZ,* PAUL W. TUCKER,† and W. F. DeVOE‡

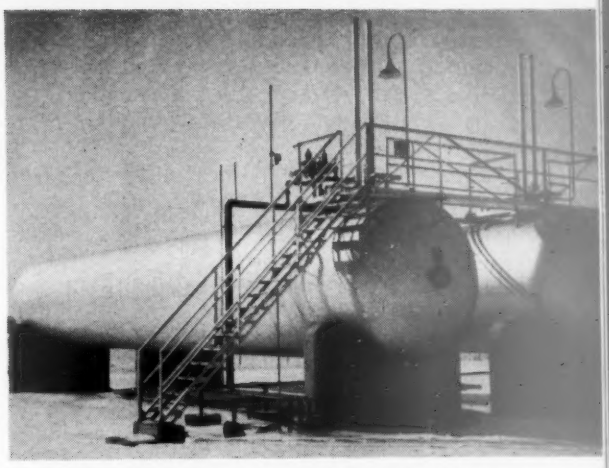

FIG. 1. Typical LP-Gas "Peak Shaving" Installation.

SALES of liquefied petroleum gas passed another milestone in 1954 with a healthy increase in volume over 1953. The outlook for 1955 appears even better with general upturn of business conditions.

Sales of LP-Gas in 1954 were 5,134,000,000 gal or 4.1 per cent over the 1953 volume. Production, storage, and transportation facilities continued to increase.

- Domestic and motor fuel sales up 9.2 per cent or 273,000,000 gal.
- Industrial and miscellaneous sales increased 2.0 per cent.
- Gas manufacturing or utility sales dropped 6.5 per cent.
- Sales of LP-Gas for chemical manufacturing were up 1.0 per cent.
- Sales of LP-Gas for manufacture of synthetic rubber components were down nearly 19 per cent.

Domestic and Motor Fuel

Sales of LP-Gas for domestic and motor fuel purposes in 1954 are estimated at 3,250,000,000 gal. This represents an increase of 9.2 per cent over comparable 1953 sales. As usual the domestic and motor fuel market is the largest segment of total sales and it was gratifying to see this increase where some other industries noticed a leveling-off this year; however, the shorter and milder winter that characterized the winters of 1951-52 and 1952-53 again prevailed and served to sharply limit larger increases in this category.

The summer sales did not hold up as well as they have in previous years due to the following reasons: The usually heavy irrigation load (fuel for the pumping units) did not start until late in the summer; and sales of LP-Gas for tractor fuel were off due to the extreme drought, which sharply curtailed the use of tractors.

There has been a very substantial increase in the use of LP-Gas for tobacco curing in the Connecticut Valley, the Southeast, and in Missouri. Small crop dehydration plants, as well as portable crop dehydration units, continue to be a good market for LP-Gas. There is a growing and widespread interest in irrigation. This interest runs the gamut from truck gardening to major farm crops and should be a good load-builder for the wide-awake dealer; however, house heating doubtless remains as the biggest single potential loadbuilder. House heating with LP-Gas is moving north. House heating in the cooler regions does call for larger storage, both dealer and customer.

The National Council for LP-Gas Promotion (formerly the National Committee for LP-Gas Promotion) was incorporated early in the year. The promotional work of the council is becoming more effective. In addition to the advertising copy prepared for the press, radio, and television, the council is working closely with important national magazines, preparing feature articles on model homes utilizing LP-Gas.

The Liquefied Petroleum Gas Association (LPGA) is cooperating fully with the Civil Defense Groups in emergency mass feeding demonstrations. It is becoming more and more obvious that LP-Gas will play a tremendous role in event of a national emergency.

It is estimated that 402,000 LP-Gas ranges were shipped during the year. This is a decrease of approximately 10 per cent from the number shipped in 1953. Sales of automatic LP-Gas water heaters are estimated at 274,500 or about 3.7 per cent under those of 1953. The shipments of LP-Gas fired floor, space, and wall type furnaces this year were almost 392,000. This was 28 per cent of the total production of this type of gas-fired appliances. LP-Gas fueled warm air furnaces represented 8 per cent of total (or 50,000) this year. Three per cent of the conversion burners shipped during the year were for LP-Gas. This trend was characteristic of the entire appliance industry (both gas and electric) for the year 1954.

Sales of LP-Gas for motor fuel during 1954 showed exceptional gains over 1953 and if it were to be treated separately in this report would exhibit the largest single category increase. As pointed out last year, it is very difficult to separate the quantity of LP-Gas used as motor fuel from the over-all domestic use. It is conservatively estimated, however, that the sales of LP-Gas motor fuel increased 25 per cent over last year. In other words, this use alone amounted to nearly 625,000,000 gal or more than 12 per cent of the total sales. There are now more than 2500 buses, 200,000 tractors, and untold numbers of trucks and taxicabs operating on

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LP-Gas. To get the total LP-Gas motor fuel market, one must add that which is used for irrigation, oil and gas well drilling, industrial tractors, lift trucks and refrigeration unit engines in cargo trucks.

Outstanding during 1954 in the LP-Gas motor fuel phase was the interest in converting industrial tractors and lift trucks and engines driving over the road cargo truck refrigeration units. Probably the most important factor in the conversion of lift trucks is the elimination of exhaust fumes. With refrigeration units, the major factors are elimination of lead fouling of spark plugs and exhaust valve problems that resulted from using gasoline under constant speed, constant load conditions. The first two LP-Gas fueled lift trucks to be approved by the Underwriters' Laboratories were announced in 1954.

It has been estimated that about 80 per cent of the farm machinery in the lower Rio Grande Valley of Texas will be operating on LP-Gas by 1957.

LP-Gas service stations are becoming a more familiar sight on the highway. ICC has reported that the LP-Gas fuel system is safer than the systems used with either of the other two major motor fuels.

Industrial, Miscelloneous Uses

Industrial and miscellaneous sales totalled 382,000,000 gal, 2.0 per cent over 1953. It is estimated that because of natural gas pipe line extensions or increased pipe line throughputs the industrial LP-Gas load itself declined slightly from last year. This seems reasonable also when one considers that one of the major industrial uses is in heat treating, which levelled off last year. Increase in miscellaneous applications, however, more than offset the industrial loss so that the net is up. More industrial "stand by" plants are being added as a protection against interrupted gas service with consequent shut-down and loss of production. One of the major railroads has stated that propane is an ideal fuel for the gas turbine type locomotive because practically no maintenance is required but they do not contemplate using LP-Gas as a fuel under present conditions of supply, storage, and cost as compared with other fuels.

The possible use of LP-Gas for "flooding" oil sands to increase the recovery from low pressure reservoirs containing viscous crude is of considerable interest.

Utility Use

Gas manufacturing demand or utility use of LP-Gas for 1954 is estimated to be about 208,000,000 gal, or 6.5 per cent less than 1953. This is due to the mild winter and the natural gas line extensions or increased throughputs. The latter two reasons are, however, the major ones. It should be pointed out that in some areas, the demand for LP-Gas for peak shaving showed sizeable increases due to the utilities taking on new house heating loads. The use of LP-Gas "in the mains" at new housing developments continues to be very popular.

For Chemical Manufacture

Sales of LP-Gas as a raw material for the manufacture of chemicals and chemical intermediates showed only a modest increase of 1 per cent over 1953, with an estimated volume of 977,000,000 gal. This increase was brought about by an upturn in demand during the final quarter.

Petrochemicals, as a group, made a much greater gain during the year, but most of the gain was due to increased use of methane and ethane in the production of anhydrous ammonia and polyethylene. Petrochemicals used in the textile industry, many of which are produced from LP-Gas, had a slow year, and the market for synthetic alcohols and various anti-freeze compounds, also large consumers of LP-Gas, was weak. These decreases were slightly more than compensated for by the requirements of new plants and full time operation of plants built in 1953.

Rubber

The demand for LP-Gas as a raw material for the manufacture of synthetic rubber components decreased by more than 18 per cent, so that the total volume is estimated at 317,000,000 gal. This reduction in the use of LP-Gas for rubber during 1954 resulted from the substantial cutback in synthetic rubber production authorized by the Federal Facilities Corporation (formerly the Reconstruction Finance Corporation, Office of Synthetic Rubber). Reductions in the synthetic rubber program resulted from a combination of several factors. The high production of automobiles during 1952 and 1953 has resulted in a considerably higher number of new cars on the road than has been normal in previous years. These cars, for the most part, are still running on their original rubber and this has affected adversely the demand for replacement tires. Tire mileage has increased over that attained during the last few years due to improved synthetic rubbers and better carbon blacks. The greater use of natural rubber (due to a softening of the natural rubber market) and the reduction in new car tire demands as a result of the 1954 cutbacks in automobile production as the industry prepared for the introduction of the new models were factors in reducing total rubber requirements also.

Safety Standards

The LP-Gas industry continues to enjoy a good safety record in comparison with competing forms of fuel and energy. This is due to continuing attention to this matter by all phases of the industry. A new section devoted exclusively to LP-Gas service stations has been added to the NFPA Standard No. 58 for the Storage and Handling of Liquefied Petroleum Gas. Other revisions in the standards have been made to adequately provide for industrial tractors and lift trucks and cargo heating and refrigeration. NFPA Standard No. 59, which covers liquefied petroleum gas at utility gas plants, has been revised for the first time since 1949. Several major municipalities have revised their ordinances to permit and properly provide for the storage, transportation, and utilization of LP-Gas within their corporate limits. This is definitely a move forward and should be encouraged.

Supply

The production potential of LP-Gas continues to increase despite curtailment in crude-oil production and crude runs to stills at refineries. There were 20 new sources of LP-Gas completed or nearly completed in 1954 with a total production potential of over 700,000,000 gal. This included 19 natural gasoline plants and one major refinery addition. Obviously, this increased capacity was not available for the entire year as some of the larger sources were completed near the end of the year. It is estimated that 15 new plants will be added in 1955 with a product potential of upwards of 200,000,000 gal. The production capacity is available to satisfy large increased demands for LP-Gas.

Many in the LP-Gas business are wondering how the recently imposed regulation of independent natural gas producers is going to affect their business. Unless Congress acts to remove this regulation, it clearly will be detrimental to the LP-Gas business. Natural gas is just one of the energy products of the petroleum industry, that along with LP-Gas and refined products, compete with each other. About one-third of the natural gas is produced with oil from the same wells. LP-Gas comes from natural gasoline plants that process wet gas to remove the liquids and from refineries processing crude oil. Any regulation that adversely effects the production and marekting of any of these products, all of which share in the cost of exploration, development,

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Table 1. Marketed production of LP-gas

Year	Gallons (in thou.)	Increase, per cent	Domestic and motor fuel*	Increase, per cent	Industrial misc. (1)	Increase, per cent	Gas mfg.	Increase, per cent	Chemical mfg.	Increase, per cent	Rubber components	Increase, per cent
1922	223	....	Sale of liquefied petroleum gas confined primarily to bottled gas business prior to 1928									
1923	277	24.4										
1924	376	36.0										
1925	404	7.2										
1926	465	15.2										
1927	1,091	134.6										
1928	4,523	314.6	2,600	....	400	....	1,500	....				
1929	9,931	119.6	5,900	126.9	1,500	275.0	2,500	66.7				
1930	18,017	81.4	11,800	100.0	2,200	46.7	4,000	60.0				
1931	28,770	59.7	15,295	29.6	7,172	226.0	6,303	57.6				
1932	34,115	18.6	16,244	6.2	8,167	13.9	9,703	53.9				
1933	38,931	14.1	16,626	2.3	13,987	71.3	8,318	—14.3				
1934	56,427	44.9	17,681	6.3	32,448	132.0	6,298	—24.3				
1935	76,855	36.2	21,380	20.9	47,894	47.6	7,581	20.4				
1936	106,652	38.8	30,014	40.4	67,267	40.4	9,371	23.6				
1937	141,400	32.6	40,823	36.0	62,610	(2)	11,175	19.3	26,792	....		
1938	165,201	16.8	57,832	41.7	62,094	0.0	12,386	10.8	32,299	20.5		
1939	223,580	35.3	87,530	51.4	93,723	49.4	15,435	24.6	26,892	—16.7		
1940	313,456	40.2	134,018	53.1	124,482	32.8	20,285	31.4	34,671	29.0		
1941	462,852	47.7	220,722	64.7	172,669	68.6	25,255	24.5	44,206	27.5		
1942	585,440	26.5	303,857	37.6	197,179	14.2	31,366	24.2	53,038	20.0		
1943	675,233	15.3	344,962	13.6	237,396	20.4	37,519	19.6	55,356	4.4		
1944	1,060,156	(4)	445,617	29.2	254,590	7.3	45,879	22.3	151,985	175.0	162,085	....
1945	1,276,766	20.4	533,262	19.7	256,577	0.8	53,849	17.4	224,291	47.5	208,787	28.8
1946	1,704,262	33.5	758,466	42.2	253,745	— 1.1	86,660	61.0	311,499	38.8	293,892	40.8
1947	2,209,797	29.7	1,150,538	51.7	274,125	8.0	169,332	95.4	414,267	33.0	201,535	—31.4
1948	2,736,801	23.8	1,473,289	28.1	275,883	0.6	237,638	40.3	524,350	26.6	225,641	11.9
1949	2,836,599	3.6	1,627,550	10.5	247,103	—10.4	239,210	0.6	544,886	3.9	177,850	—21.1
1950	3,482,567	22.8	2,022,464	24.3	355,456	(3)	251,694	5.2	624,468	14.6	228,485	28.5
1951	4,227,275	21.4	2,456,804	21.6	269,408	(3)	281,692	11.9	844,507	35.2	374,864	64.1
1952	4,477,379	5.9	2,636,736	7.4	338,959	26.0	259,697	— 7.8	870,990	3.1	370,997	—1.1
1953	4,932,009	10.2	2,977,418	12.9	374,233	1.04	222,430	—14.4	967,427	11.1	390,501	5.3
1954	5,134,000	4.1	3,250,000	9.2	382,000	2.0	208,000	— 6.5	977,000	1.0	317,000	—18.7

*Household use plus other requirements by these customers such as irrigation pumping, tractor fuel, flame weeding, chicken brooding and similar uses. Included also is LP-Gas sold by domestic distributors but used for industrial purposes. Included also, in years following 1950, is LP-Gas sold direct by producers and marketers solely for fueling internal combustion engines.

(1) For all years prior to 1951, include LP-Gas sold for refueling internal combustion engines.

(2) Not comparable due to segregation of chemical manufacturing.

(3. Not comparable due to change in method of reporting LP-Gas sold for refueling internal combustion engines.

(4) Not comparable due to inclusion of rubber components.

REMARKS: In this table total sales for all years except 1954 were obtained from U. S. Bureau of Mines reports. Distribution for the years 1931 to 1953, inclusive, was obtained from the same source. All other volumes were estimated by the writers. The total sales volume includes all LP-Gas (propane, butane, and propane-butane mixture) when sold as such. Until 1944 the sale of pentane when sold for any purpose other than motor fuel blending was included. Since then it has been excluded. It does not include butane when blended with heavier petroleum fractions for motor gasoline purposes. Inter-company sales transactions such as purchases of LP-Gas by one company from other companies and resold as LP-Gas have been eliminated in order to avoid duplication of sales figures.

NOTE: A direct comparison of 1954 LP-Gas sales with those of 1953 reported by the Bureau of Mines, indicates a substantial decrease for 1954. However, the Bureau of Mines changed the method of reporting LP-Gas statistics starting January 1, 1954. This change in reporting procedure makes such a direct comparison of sales for these two years unrealistic. The two major changes were: (1) LP-Gases blended into gasoline were reported by gasoline plants (shipper) in 1953, but in 1954 were reported by refineries (receivers). These reports showed more LP-Gas being blended into gasoline, leaving less for "other uses." Thus, it is necessary to consider this change when making a comparison. (2) The reports for 1954 contain more complete coverage of LP-Gas in underground storage. This is an important change, since that which is not reported as in storage is shown as sales. These are the two major changes in the procedure. However, it is felt that the revision makes the entire report more accurate and realistic, although it does not show a breakdown of demand for the various uses.

and production, will tend to increase the cost and decrease the supply of the others. And if the cost of LP-Gas is increased and its supply decreased below market demand level, its competitive position with respect to coal, electricity, and other energy sources is endangered.

Natural gas was sold at distress prices for years before the tremendous increase in demand of the past few years occurred. Over the long term, competitive demand will be the only factor that will cause natural gas to adjust to proper price levels in relation to other fuels. A natural gas price artifically depressed by regulatory forces, which may well occur in many areas during the first several years under regulation, will place the LP-Gas marketer at a competitive disadvantage. Perhaps of most importance, such control will directly or indirectly lead to regulation not only of natural gas but of the rest of the products of the petroleum business, including LP-Gas.

Storage

The storage facilities of LP-Gas are at an all-time high. Storage has been increased at all levels—producing, distributing, and consuming.

It is interesting to note that percentagewise, more tanks are being sold in the 500 and 1000-gal size; however, with the continued swing to LP-Gas house heating, consumer storage is still too often undersized to meet the requirements.

The LP-Gas industry in 1954 continued the rapid development of underground facilities for LP-Gas. The 458,000,000 gal of underground storage in use at the end of 1954 exceeded storage in use a year earlier by 212,000,000 gal, a gain of approximately 86 per cent. At the year's end an additional 250,000,000 gal of storage was under construction or proposed. This is shown in Table 2.

Most of the storage developed and proposed is situated in salt formations in gas producing areas. The industry has taken advantage of lower construction costs for storage facilities in the vast Permian salt beds, extending from central Kansas through the Oklahoma and Texas Panhandles, across West Texas and southern New Mexico and in the numerous salt domes along the Gulf Coast in southern Louisiana and Texas. Some use has been made of storage space in sand formations underlying many producing facilities. The underground storage in use east of the Mississippi River and generally north of the Mason-Dixon Line totals approximately 34,000,000 gal.

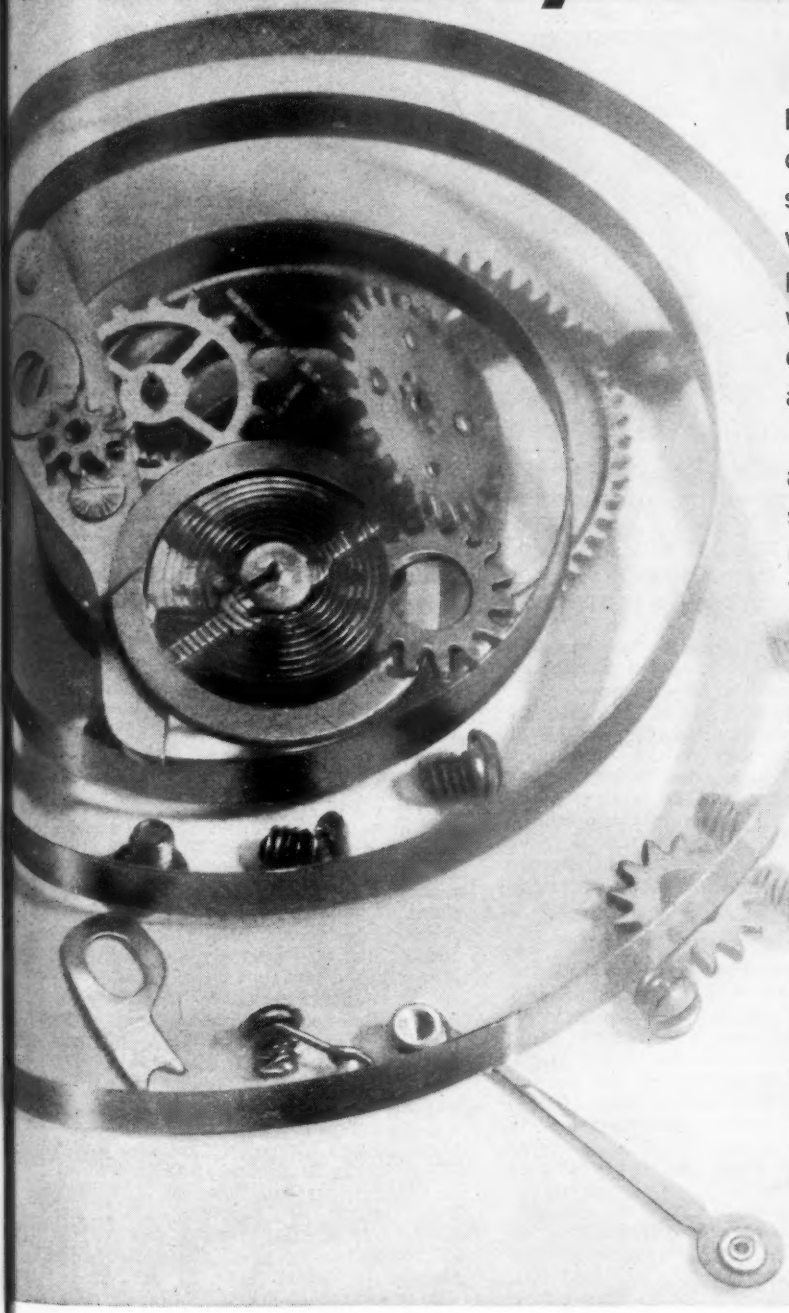
In recent months construction has started and plans are being made for additional underground storage at refineries and terminals along the East

Table 2. Underground storage for LG-Gas.

	Jan. 1, 1954 1,000,000 gal.	Jan. 1, 1955 1,000,000 gal.
Storage in use		
Caverns in salt formations	212.1	383.1
Mined caverns	16.9	27.8
*Storage in sand formations	17.0	47.5
Total storage in use	246.0	458.4
Storage under construction		
Caverns in salt formations	93.9	132.9
Mined caverns	15.8	7.6
Total storage under construction	109.7	140.5
New storage proposed		
Caverns in salt formations	99.7	92.6
Mined caverns	20.2	16.8
Total new storage proposed	119.9	109.4
Total storage (in use, under construction and presently proposed)		
Caverns in salt formations	405.7	608.6
Mined storage in sand formations	52.9	52.2
*Storage in sand formations	17.0	47.5
Total	475.6	708.3

* The capacities of storage in sand formations are reported as the maximum volume used thus far as the ultimate capacity is unknown.

The Hard Way to Buy a Refinery



Buying a petroleum refinery in "pieces" from different sources, each with its own design standards and materials specifications, is somewhat like buying a watch the same way. An expert can put the units together and make them work. But it's a lot simpler, and usually more economical, to buy the complete "package"—assembled and already running when you get it.

When planning a new refinery, or modernizing an existing one, there are many economic reasons why it pays to have a single contractor responsible for integration of the entire project. These include centralized purchasing power; shorter and flexible construction schedules; uniformity of design factors in process equipment; and the elimination of duplicate construction managers and their staffs.

The M. W. Kellogg Company, world's leading designer and builder of petroleum refineries, offers a complete "packaged-plant" contract to the petroleum and petro-chemical industries. It covers process engineering; plant design and construction of the entire job, including off-site installations such as tanks, loading facilities, docks, roads; supervision until on stream; and a production guarantee. We welcome the opportunity to discuss with you the many advantages of The M. W. Kellogg "packaged-plant" contract.

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Coast and in the eastern part of the United States. The trend toward underground storage of LP-Gas in the northeast has been slow in developing but may be expected to expand during the coming year; however, the total underground storage foreseen for this important distributing area is less than 10 per cent of the total underground storage.

Transportation

It is now estimated that there are a total of 26,144 pressure tank cars in service suitable for handling LP-Gas; however, about 7500 of these cars are in other service, principally chemical. This would leave an estimated 18,644 cars in LP-Gas service. More than 2100 tank cars were added to the LP-Gas fleet during 1954. Another seagoing barge was christened and put into service this year. This makes a total water fleet of two LP-Gas ships, three dual cargo ships, four propane barges (two inland waterways, two seagoing) and one butane barge. Although a substantial amount of the total LP-Gas is currently moved by pipe line, new LP-Gas pipe line projects have been announced for Mexico, USA, and Canada. Truck movement is increasing with the trend toward the use of large "blimp type" or single barrel units because of increased payload.

Exports

Sales of LP-Gas for export are up again about 30 per cent, totalling 38,500,000 gal. New extraction facilities have been proposed for Canada, Mexico, and England but are not yet in operation. These plants may affect the export market, however, the demand is on the upswing and the foreign LP-Gas market is bright.

Outlook

The gain in LP-Gas sales for 1954 was a healthy one although not equal to the phenomenal gains of earlier years.

The house heating market offers one of the greatest potentials for large volume increases in LP-Gas sales.

The motor fuel market is expanding and achieving wider acceptance. It also offers great possibilities for increased volume.

The air conditioning field offers a growing market for year-around air conditioning using gaseous fuels.

In view of the increasing sharp competition in the fuel market, the LP-Gas industry must step up its sales efforts and render the best possible service to its customers to continue to enjoy substantial gains each year. With such increased effort and the general upturn of business activity, 1955 looks promising for the LP-Gas industry. * * *

REFINING AND PETROCHEMICAL PERSONALS

Representatives of the Central Engineering Group and Rubber Plant attending Sinclair Refining Company's maintenance-engineering symposium at Philadelphia: Top Row: L. Chaney, W. Hitchcock, C. A. Williams, L. P. Foster, R. Wilson, H. C. Kuhn, E. Asmus, E. R Hoyle, G. Hill; middle row: J E. Kendall, W. A. Myrick, T. C. Wilson, F. B. Bluhm, F. Bruns, A. Eron, C. V. Lynn, N. Pennels, and bottom row: M. Neterer, R. B. Smith, W. R. Argyle, T. D. Tifft, J. Bell, T. Kimball, W. S. Gullette, O. F. Campbell.

Howard D. Hartough has been appointed to research on new petrochemicals and catalysts at the Marcus Hook, Pennsylvania, laboratories of the Houdry Process Corporation. Hartough holds 70 patents and has authored 30 publications. For 13 years, the research chemist worked on petrochemicals and the development of thiophene at the Socony-Vacuum laboratories. He left there to join the Hercules Powder Company where he was engaged in market development for petrochemicals until joining Houdry.

Roger Maurice Serre, of New York, has joined the staff of senior sales representatives of The M. W. Kellogg Company. A chemical engineer, Serre has had extensive petroleum experience in Europe and South America as well as in the United States. He will represent Kellogg in the negotiation of engineering and construction contracts in the petroleum and petrochemical fields.

John M. McAneny has been appointed manager of the sales administration department of Kellogg. A chemical engineer, McAneny has been associated with the company for 12 years, serving in various supervisory capacities for sales and promotional activities. Prior to joining Kellogg, he began his professional career with The Tidewater Associated Oil Company, working for 14 years. He is a graduate of the University of Washington, where he earned his bachelor's degree in chemical engineering and his master's in chemistry.

S. R. McMurry, who has been on special assignment in the Bartlesville, Oklahoma, office of Cities Service Oil Company, has returned to Ponca City, Oklahoma, as manager of the Cities Service refinery there. **D. R. McConnohie,** who was plant manager during McMurry's assignment in Bartlesville, was transferred to the company's East Chicago, Indiana, refinery on special assignment. **C. W. Rohler** is the newly-appointed chief process engineer at the Ponca City refinery. McMurry was first employed by Cities Service in 1924 and was transferred to Ponca City in 1950 as plant manager, after serving 20 years in various operational and supervisory positions at East Chicago. McConnohie joined Cities Service at its East Chicago refinery in 1936 after graduating from Michigan State College with a degree in chemical engineering. Rohler joined Cities Service in 1949 and served at the East Chicago refinery before his transfer to the Bartlesville process engineering section in 1951. He is a graduate of Colorado School of Mines.

Howard D. Hartough

Roger Maurice Serre

John M. McAneny

Bradlee V. B. Postell has been named assistant to **Dr. Howard I. Cramer,** vice president, development, Sharples Chemicals Inc., subsidiary of the Pennsylvania Salt Manufacturing Company. In this capacity he will assist in staff activities incident to the Company's development program. Postell attended Deerfield Academy and was graduated from Princeton University where he majored in chemical engineering, and served as editor of the *Princeton Engineer*. In 1952 he received the M.B.A. degree of the Harvard Graduate School of Business Administration.

J. G. (Det) Detwiler, widely known petroleum technologist, has been appointed as petroleum consultant to Foster D. Snell, Inc., of New York City. Detwiler was technologist with The Texas Company. He was supervisor of tests and specifications from 1946 to 1953, when he retired after 43 years of service with that company. At the Snell organization he will aid in the work of its scientific and technical organization in the petroleum and petrochemicals fields.

Officers were elected at the annual meeting of the National Lubricating Grease Institute. President is **Hugh L. Hemmingway,** The Pure Oil Company; vice president, **William M. Murray,** Deep Rock Oil Corporation; and directors, three-year term, **M. R. Bower,** Standard Oil Company of Ohio, **A. J. Daniel,** Battenfeld Grease and Oil Corporation, **G. A. Olsen,** Sunland Refining Company, **F. E. Rosenstiehl,** The Texas Company, **William H. Saunders, Jr.,** International Lubricating Corporation, and, **B. G. Symon,** Shell Oil Company.

Jerry C. Walker is promoted to the newly-created position of field sales manager, by Frontier Chemical Company. Previously, Walker has managed the company's petroleum sales and this move will bring him into all phases of company sales. **Robert J. Redmond,** formerly sales representative in the Texas area, will be made sales coordinator to handle liaison work between production, sales and customers.

John J. Waybright, refinery engineer and executive, became assistant refining coordinator in connection with North American refining activities for Standard Oil Company (New Jersey) in a series of appointments. Waybright's appointment transferred him to New York from Everett, Massachusetts, where he has served the past two years as refinery manager for Esso Standard Oil Company.

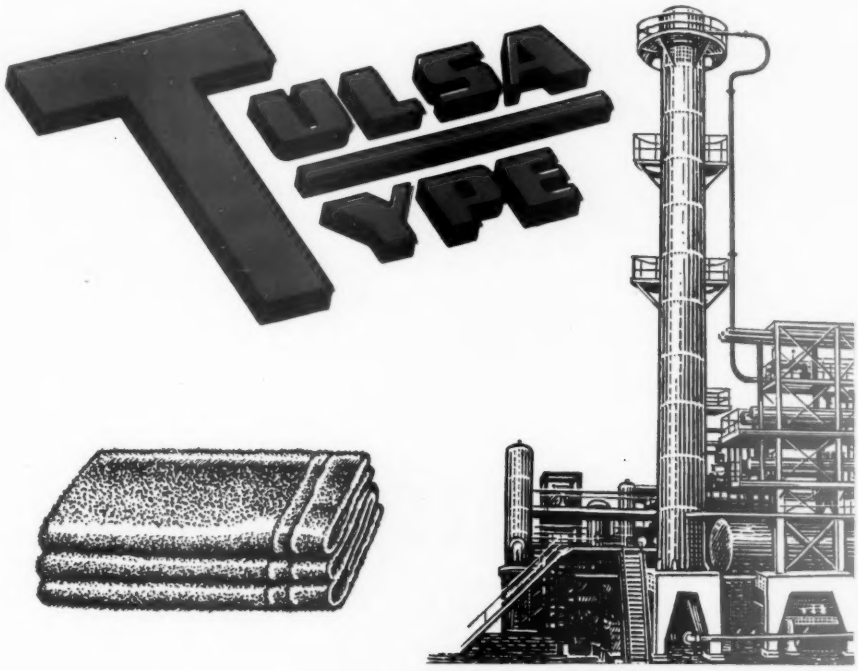
Also announced is the appointment of **Paul J. Harrington** as general technical advisor covering technical and associated economic problems in the coordination of Jersey refineries. This assignment transferred him from Standard Oil Development Company, Jersey's research and engineering affiliate, which he had served as assistant chief engineer since 1950.

Additional appointments in the refining coordination department included assignments of **A. T. Rynalski,** and **J. E. Woodward** to area advisory posts. Rynalski became area advisor covering refining activities of two Caribbean affiliates, Creole Petroleum Corporation and Lago Oil and Transport Company, Ltd. Woodward became area refining advisor for the United Kingdom, Erie and France. He succeeded to the post presently held by **M. J. Jamieson** who will retire February 1, after 35 years of service with the Jersey Standard organization.

Barnett F. Dodge, head of the Department of Chemical Engineering at Yale University, has been elected president of the American Institute of Chemical Engineers for 1955. In 1925 Dodge became assistant professor in Chemical engineering at Yale University. From 1935 up to the present time, he has been professor of chemical engineering, and since 1931, chairman of the chemical engineering department. In addition to his other activities, Dodge has acted as consultant to the Phillips Petroleum Company and Oneida, Ltd., as well as being a partner in the consulting firm of Dodge, Bliss and Walker. He was a Fulbright lecturer in 1951.

J. W. Healy has been appointed assistant superintendent, and **R. J. Baechle** and **W. P. Thomson** group leaders, at Standard Oil Company's research department laboratory, Wood River, Illinois. Healy joined Standard at its Whiting, Indiana, laboratories in 1947. He worked in the pilot plant division until his transfer to Wood River in 1951, where he has served as group leader. He is a graduate of Pennsylvania State College with an advanced degree from Massachusetts Institute of Technology. Baechle, a chemical engineering graduate of the University of Illinois, started with Standard in 1951. He has been at the Wood River laboratory since then.

Thomson is being transferred to Wood River from the chemical products division of the company's Whiting research laboratories. He joined Standard in 1952. He is a graduate of Purdue University and also has an advanced degree from M.I.T.



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Equilibrium Constants of Combustion Gas Reactions

George E. Mapstone

Many reactions can take place in fuel gases at high temperatures and it is frequently necessary to calculate the effect of temperature and pressure on the equilibrium conditions. This nomograph has been designed to present the data of Lewis and von Elbe* on the relationship between the equilibrium constants and temperature in a convenient and readily usable form.

The equilibrium constants are calculated as follows:

Eg. i. $CO + H_2O \rightarrow CO_2 + H_2$

$$K_p = \frac{(CO_2)\,(H_2)}{(CO)\,(H_2O)}$$

Eg. ii. $C + 2H_2O \rightarrow CO_2 + 2H_2$

$$K_p = \frac{(CO_2)\,(H_2^2)}{(H_2O)^2}$$

etc., where the terms in the brackets refer to the partial pressures of the gases involved.

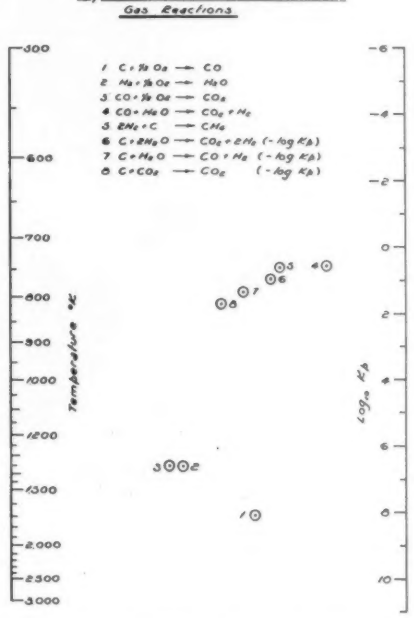
For 3 of the reactions listed (Nos. 6, 7, and 8) log K_p decreases instead of increasing with the temperature as it does for the other reactions. In order to simplify the nomograph the sign of log K_p has been reversed for these 3 reactions. This is best shown in the following examples.

Example 1. What is the equilibrium constant for the reaction

$$CO + H_2O \rightarrow CO_2 + H_2$$
at 1200 deg K. ?

Connect 1200 on the temperature (left hand) scale to point 4 and extend to give log K_p = —0.7 on the right hand scale.

Now log K_p = — 0.7 = 1.3, whence K_p = 0.2.


Equilibrium Constants Of Combustion Gas Reactions
1 C + ½ O2 → CO
2 H2 + ½ O2 → H2O
3 CO + ½ O2 → CO2
4 CO + H2O → CO2 + H2
5 2H2 + C → CH4
6 C + 2H2O → CO2 + 2H2 (- log Kp)
7 C + H2O → CO + H2 (- log Kp)
8 C + CO2 → 2CO (- log Kp)
Temperature °K
Log10 Kp

Example 2. What is the equilibrium constant for the reaction

$$C + 2H_2O \rightarrow CO_2 + H_2$$
at 1200 deg K. ?

Connect 1200 on the temperature (left hand) scale to point 6 (for this reaction) and extend to give log K_p = — 1.5 on the right hand scale. In this case the scale value is of — log K_p so log K_p = + 1.5, whence K_p = 32.

Reference

*Lewis and von Elbe, *J. Amer. Chem. Soc.*, 57; 612, (1935).

Equilibrium Dew Points vs Contact Temperature for DiMyfene Glycol - Water Solutions
Water Weight Per Cent in DiMyfene Glycol
Contact Temperature °F
Gas Equilibrium Dew Point Temperature °F

Equilibrium Dew Points Over Wet Diethylene Glycol

George E. Mapstone

Diethylene glycol is a commonly used reagent for the dehydration of natural gas. The amount of drying achieved is a function of the contact efficiency, the contact temperature and the water content of the diethylene glycol. The equilibrium relationship between the dew point of the gas, the contact temperature and the water content of the glycol developed by Gordon* is presented here in the form of a convenient nomographic chart. For routine use of the chart the water content of the glycol can be related to some property of the mixture such as the boiling point or the specific gravity, and this selected property can be marked in by the user on the composition scale.

Example: What will be the dew point of a gas brought to equilibrium over diethylene glycol containing 10 per cent of water at 50 F? Connect 50 on the temperature (left hand) scale with 10 per cent water on the composition scale (center) and extend to give the dewpoint of 21 F on the dew point (right hand) scale.

Reference

*Gordon, J. A., *The Petroleum Engineer*, 25; (12), A-74-86, (1953).

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Corrosion Prevention in Cooling Water Heat Exchangers†

J. D. MUNRO

THE shell and tube exchanger is a most vital part of the petroleum refinery. In a modern plant, this equipment is more numerous than any other type of process equipment. Aside from representing a considerable share of the investment, it consumes a major percentage of all maintenance costs.

The heat exchanger, however, is greatly responsible for the high degree of efficiency that exists in the petroleum refinery today.

Because of the complexity of many new process units and the highly competitive spirit of the industry, the utmost efficiency of heat exchangers is necessary. But also because of the complexity of the heat exchanger itself and the conditions to which it is exposed, many problems arise. These must be overcome if satisfactory and economical operation are to be realized.

Paramount of the problems encountered are those attributed to corrosive environments of which cooling water, particular sea water, has been the greatest single offender. It has been in combatting the many corrosion problems caused by cooling water that most time and energies devoted to heat exchanger problems have been spent. It is apparent, after many years of trials, experiments, development and research, that this problem can be at least controlled in all cases.

Standard Oil lays no claim to having eliminated its cooling water corrosion. It is still a major problem. During the post-war years, however, a considerable reduction in exchanger corrosion and maintenance has been achieved. This reflects the magnitude with which efforts have been concentrated on corrosion mitigation. It remains the task to disseminate the best of the available methods and techniques, as well as the general knowledge of how and where to use them, to a world-wide organization of refineries. This article is considered to be a contribution to the over-all effort.

†Presented during the meeting of the American Petroleum Institute's Division of Refining, Houston Texas, May 10, 1954, under the title "Corrosion and Prevention Heat Exchangers in Cooling Water Service."

Corrosion—Types and Causes

The deterioration of materials exposed to cooling water in an exchanger is caused by numerous corrosion phenomena created by particular characteristics or the environment influence of the water. Complete understanding and recognition of these phenomena are essential if corrosion is to be eliminated or controlled. There follows, briefly, the types of attack experienced.

Erosion-Corrosion. This phenomenon occurs mainly at tube ends as shown in Fig. 1 and is aggravated when solids are present in the coolant. Often the tube ends erode predominantly on one side and formation of longitudinal, rounded grooves is typical. High velocity, insufficient crossover area, abrupt change in direction of flow, entrained air, and solid particles are promoting factors.

Galvanic Action. The use of dissimilar metals for adjacent parts of an exchanger can cause depolarization and severe galvanic corrosion. Although this galvanic action may take several forms, it frequently promotes dezincification. High water temperature can greatly accelerate this form of deterioration.

Graphitization. Cast iron in flowing sea water undergoes a process of deterioration known as graphitization. Fig. 2 shows typically severe results from graphitization in a floating tube sheet cover. This action is usually accelerated by the presence of brass tubes and tube sheets which are protected by the sacrificial corrosion of the iron. Graphitization is the dissipation of iron at the surface by dissolution in water, leaving a soft matrix of graphite.

At some indeterminate point during this process, the surface of the cast iron part is so heavily graphitized that it

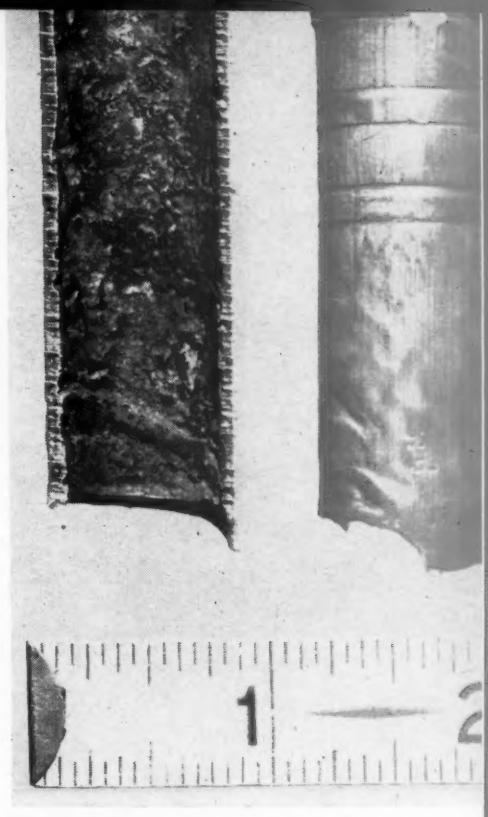

FIG. 1. Tube-end corrosion-erosion.

becomes more noble than (cathodic to) the brass tubes and tube sheets. With this reversal of polarity, corrosion of the brass becomes severe. This reversal may take several years to occur, which explains why in many cases inconsistent service life may be experienced with various parts of an exchanger. High water temperature promotes graphitization and can also hasten the change in the polarity of the iron with respect to the brass surfaces.

Impingement. Impingement attack occurs generally in and near the inlet ends of tubes but occasionally it may extend along the entire length of the tube. Typical are pits with smooth walls and sharply defined borders, elongated and becoming shallower in the direction of flow.

Dezincification. The mechanism of this deterioration of a brass is that the zinc and copper both go into solution together and the copper is subsequently redeposited on the base metal surface in the form of a porous mass or layer. This metal deterioration most commonly occurs in two forms, namely, plug-type and layer-type.

1. Plug-Type. This type of attack is a localized one that generally is caused by sediment and sometimes, though infrequently, by a localized inconsistency in the alloy composition. Its inception points are scattered at random inside the tube.

The attack progresses rapidly from these inception points and often results in early penetration. High metal tem-

Ingersoll-Rand Pumps circulate the "Life Blood" of another great refinery.

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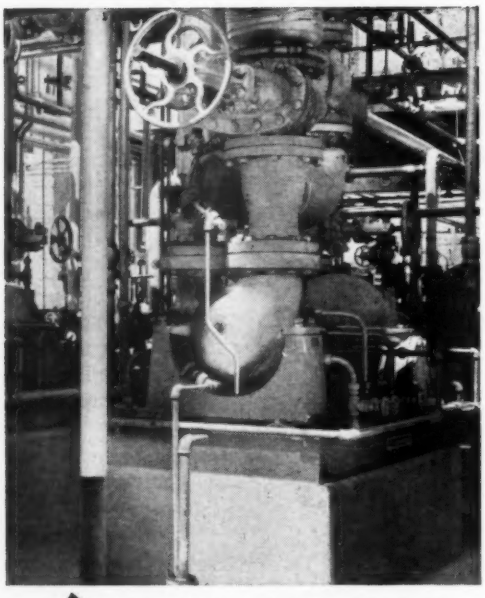

▲ Three I-R vertically-split, single-stage pumps on feed preparation service for Cosden's Platformer.

The Cosden Refinery in Big Spring, Texas marks the first installation of a combination Platforming and Aromatics Recovery Plant for simultaneous production of nitration-grade benzene, toluene and xylene from petroleum hydrocarbons.

Here, as at all petroleum processing plants, *centrifugal pumps* are the heart of the entire operation—circulating the liquids that constitute its "life blood" through miles of piping, processing units and storage tanks. To stay "on stream," operating engineers can take no chances on performance and dependability when it comes to process pumps.

At Cosden, as in refineries the world over, Ingersoll-Rand pumps and compressors are living up to their reputation for continuous, heavy-duty performance year after year, with minimum attention and maintenance.

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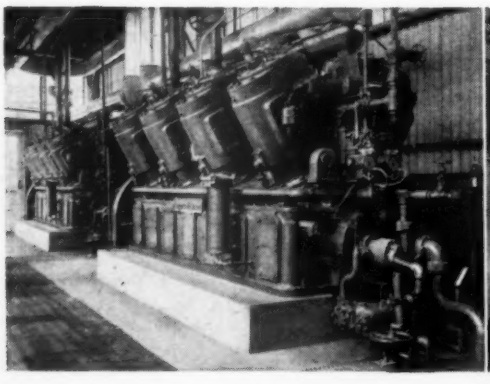

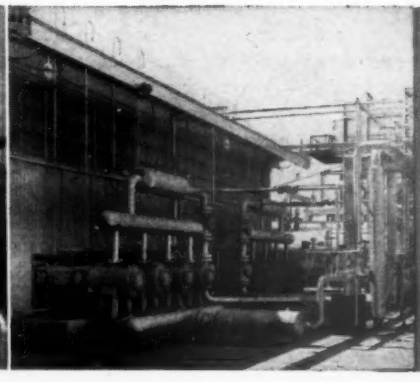

Two Ingersoll-Rand 8 XVG gas-engine-driven compressors, with non-lubricated compressor cylinders, supply clean, oil-free hydrogen to the Platformer at 850 psig. Compressor cylinders are outside the building, separated by fire-wall construction as shown in the first photo at left. A third unit is now being installed to increase capacity.

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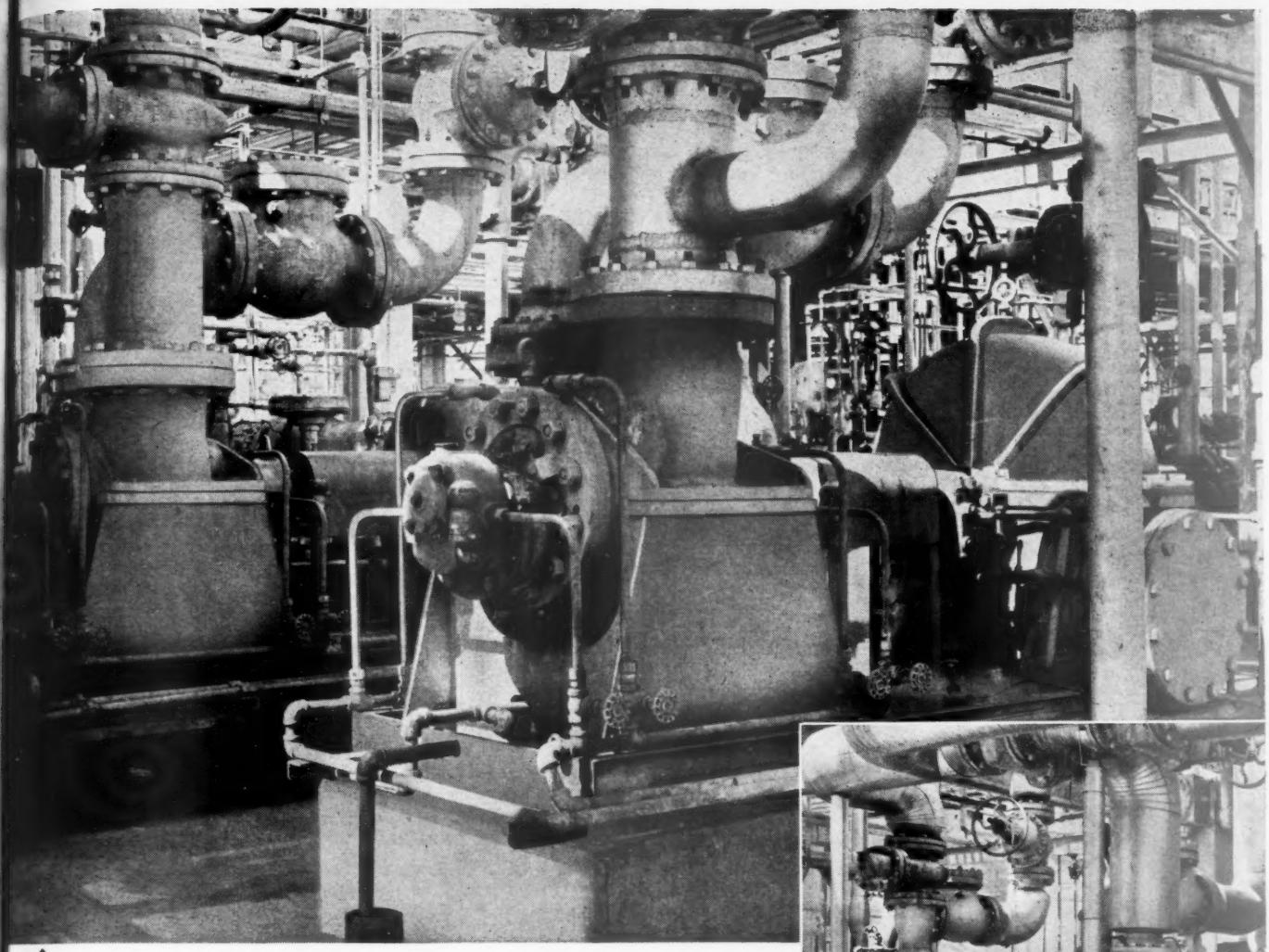
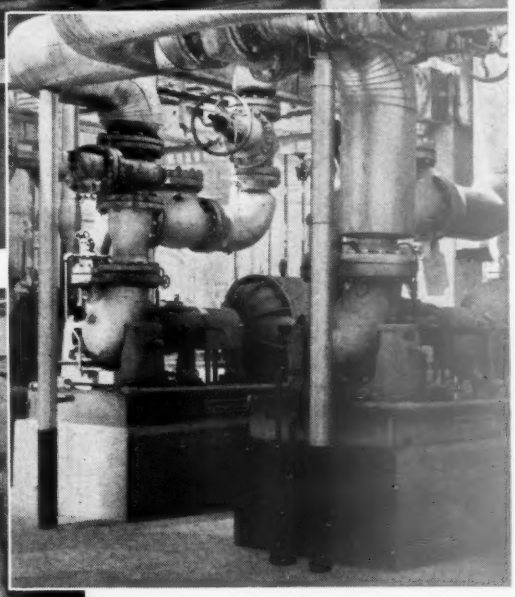
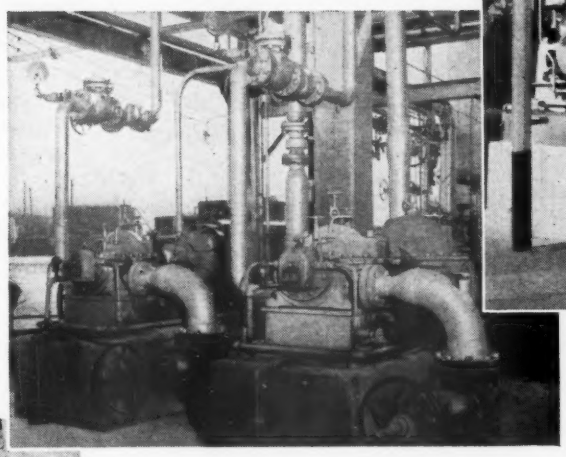


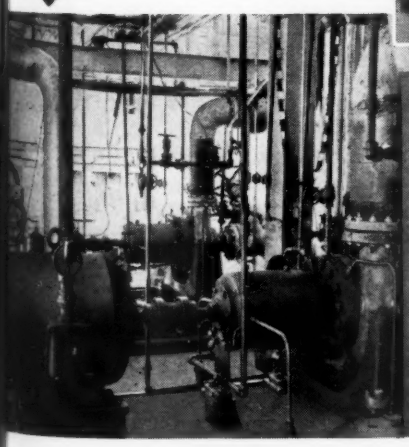
These two I-R single-stage, vertically-split units circulate 950 gpm of solvent through the Aromatics Recovery Plant at 485' head.

On the toughest of refinery jobs, these I-R slurry pumps have given dependable service. 600° gas oil, containing .8 lb/gal of catalyst is circulated through heat exchangers.



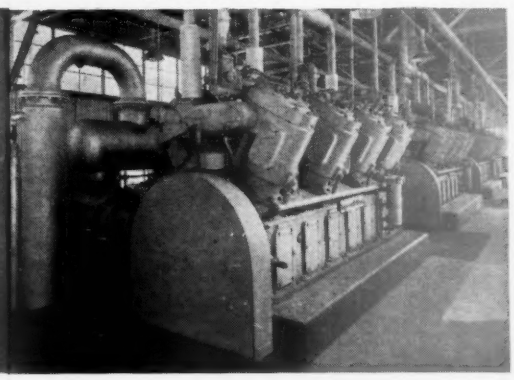
These two-stage pumps charge the Platformer with depentanized gasoline or naptha. Similar units are on boiler feed service at Cosden.





I-R COMPRESSORS SERVE CAT-CRACKER AND PLATFORMER

The four Ingersoll-Rand gas-engine-driven units at the right compress recovery gas from the cat-cracker to 215 psig. Their successful performance record has resulted in the installation of five other gas-engine compressors at Cosden.



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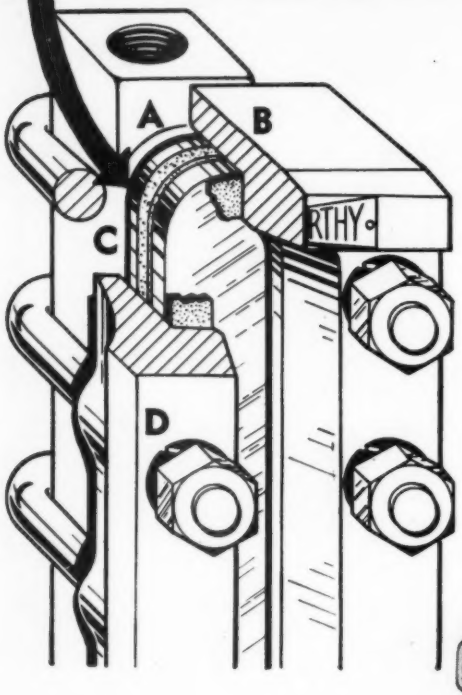

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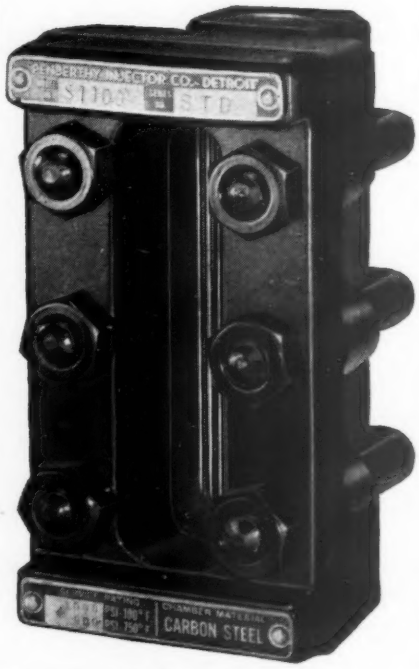

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The Author

J. D. Munro is head of the corrosion group in Standard Oil Development Company, and has been in this field since 1946, after completing two years as commanding officer of the Persian Gulf Area petroleum inspection and procurement base. A graduate of Cumberland University, Lebanon, Tennessee, he joined Standard Oil of New Jersey and has been assigned to both domestic and foreign refineries since then.

perature can greatly accelerate the attack. It can be minimized by maintaining reasonable water velocities which prevent deposition of solid particles on the tube walls and by using inhibited alloys such as Admiralty brass.

2. *Layer-Type.* This attack occurs when a brass corrodes under conditions that permit the formation of soluble copper salts and the copper salt solutions remain long enough in contact with the brass so that copper is redeposited at the expense of more brass.

This layer-type deterioration usually covers larger areas, sometimes an entire section of a tube. It is aggravated by high metal temperature as well as an anodic condition of the brass and a slightly acidic condition of the water. A porous film or a spongy sediment on the tube surface may initiate this type of attack.

Deposit Attack. Deposit or cellular attack is caused by solid particles settled on the metal surface or lodged in the tubes. These cause localized breakdown of the protective film under the deposit that results in a small area becoming anodic relative to the large surrounding area, still covered with film. Pits form, usually with irregular edges and rough bottoms. Aggravated by the localized turbulence and, at times, high velocities caused by the obstruction, the material is deteriorated and penetrated rapidly.

Fig. 3 shows a tube sheet seriously fouled with marine growth. This can be a primary cause of extremely rapid wastage of metal beneath, such as illustrated by the corroded tube sheet in Fig. 4, especially when other factors such as high temperature, dissimilar metals and/or bacterial corrosion may be associated with the deposit.

Stress, Cracking and Fatigue. Failures caused by cracks appearing in copper alloy parts, particularly tubes, of an exchanger during service indicate either external stresses (stress cor-

FIG. 2. Graphited floating tube sheet cover.

rosion), internally stressed material (season cracking) or cyclic stressed (corrosion fatigue).

Stress corrosion of tubes causes mainly circumferential cracks (longitudinal stress) that follow the grain boundaries. Stress-corrosion cracks are inter-granular and roughly perpendicular to the direction of the strain. Season cracking is inter-granular also, frequently a single (or double) longitudinal crack, but in tubes it sometimes forms an irregular pattern with nearly as many circumferential as longitudinal cracks.

Corrosion-fatigue cracks may be expected close to the tube sheets or other rigid supports and are circumferential and transcrystalline.

External stresses generally occur in large diameter tube bundles where considerable temperature differences exist between passes. Internal stresses usually are caused by severe cold work without stress relief in forming and subsequent rolling of tubes or by deformation beyond the elastic limit such as by denting or flattening. Cyclic stresses are likely to occur in such services as interstage and afterstage coolers in reciprocating compressor systems.

General. There are other phenomena which cause occasional material failures in exchangers. *Pitting* of steel channels and other ferrous parts occurs in fresh water services where protective linings, alloys, etc., are not generally used. *General* thinning, where the tube is attacked evenly over its entire surface, may result from the formation of loose, porous products that regularly drop off the surface or by brackish water of low pH value.

Corrosion Prevention Practices

Throughout the service life of heat exchangers many corrosion problems are experienced that can be directly attributed to one or more factors encountered in the various stages from design to ultimate maintenance. Within the scope of each of these stages lies the opportunity as well as the necessity to prevent the occurrence of a large number of corrosion problems. The following discussion covers some of Standard's practices that influence the

TABLE 2. Materials* for coolers and condensers. Current Design Practice.

	Salt water service	Fresh water service	Remarks
Tubes†	Inhibited Admiralty (1) Aluminum brass (2) 70-30 Cupronickel (0.5 Fe) (3)	Inhibited Admiralty (1) Carbon steel (6)	(1) Most commonly used for general refinery services. (2) Used where water or oil side conditions exhibit sulfide attack too severe for Admiralty. Several refineries have standardized on this material. (3) Where conditions of water temperature or velocity or impingement are too severe for (1) or (2). Also for highly contaminated water. Not in widespread use for water side corrosion prevention. (4) Linings of brass or bonded lead are local preference in some cases. (5) No lining required when fullface steel anode is used. (6) Used only when local preference dictates.
Tube sheets‡	Naval brass	Carbon steel Naval brass	
Channel	Carbon steel or cast iron, neoprene lined, 40 mils minimum thickness. (4)	Carbon steel or cast iron	
Channel cover	Rolled or forged steel, neoprene lined same as channel. (4) (5)	Rolled or forged steel	
Channel partition plates	Carbon steel or cast iron, lined same as channel per Sketches A, B or C; or solid bronze	Same as channel	
Floating tube sheet cover	Same as channel or cast brass (for small sizes and high metal temperature).	Same as channel	
Gaskets	Non-ferrous metal jacketed asbestos for floating end cover and compressed asbestos for channel end.	Non-ferrous metal jacketed asbestos for floating end cover and compressed asbestos for channel end.	
Anodes	Magnesium, zinc, or mild steel depending upon location and conditions.	Magnesium	

* Exposed to cooling water.
† Bi-metallic tubes of Admiralty and steel used in special service.
‡ Cladding on steel tube sheets generally confined to cases where bi-metallic tubes are used.

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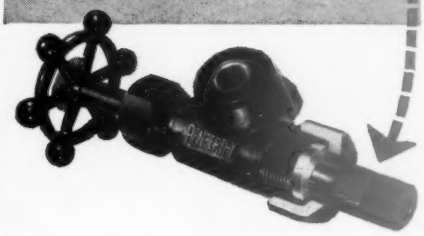

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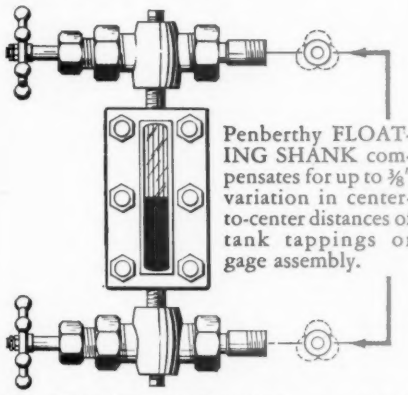

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overall service life of heat exchangers.

Process Design. This initial stage, for the most part, follows a definite pattern in that all exchangers are generally designed for specific conditions of temperature, pressure, and velocity wherein the type of water and corrosion expected are taken into consideration. Process design practices that are related to corrosion mitigation are presented briefly below.

1. Temperature. Each exchanger is handled separately during design. Design outlet water temperature is set at 110 F for salt water and 120 F for fresh water. Inlet water temperatures vary from 65 to 93 F during design depending upon refinery location. No leeway above the design outlet temperature is considered except under special circumstances, because severe corrosion difficulties are abetted by excessive temperatures.

TABLE 1. Favorable velocities for water entering tubes.

Material	Most favorable	Range
Carbon steel*	4.0 (fps)	2.5–6 (fps)
Red brass	2.5	2.5–4
Admiralty (inhibited)	3.0	2.5–5
Aluminum brass	5.0	4–8
90/10 cupro-nickel	7–8	6–12
70/30 cupro-nickel	7.5	5–10
Monel	8.0	6–12
Type 316 alloy steel	10.0	8–15

*Fresh water only.

The rate of corrosion attack on a metal roughly doubles with each 20 F rise in water temperature. Also, with excessive temperature, depositions of scale can occur with certain types of water plugging tubes rapidly. To facilitate adequate control of water temperatures, thermometers and temperature indicator (TI) points, depending upon the service, are provided during design.

2. Velocity. It is recognized that the cooling water velocity is one of the most important, if not most decisive, of all factors relating to exchanger corrosion. Good design practice, therefore provides for a:

a. Minimum water velocity of three feet per second (fps) for salt water or silty fresh water services and two and one-half feet per second for non-silty fresh waters.

b. Control valve normally in the exchanger water outlet line.

Control of velocity is every bit as critical as the velocity itself. Table 1 lists favorable velocities for most design conditions as indicated by Standard's experience.

3. Pressure. Most exchangers are designed for a battery limits water pressure of 35 psi. Adequate water pressure is essential if trouble free service is to be attained. Low supply pressure can create an undesirable syphon and possibly a vacuum in exchangers located in elevated structures.

This vacuum can result in flashing of the salt water in the tubes causing extreme overheating and accelerated corrosion from salt and solids depositing on the metal surfaces. In most instances, overhead condensers are involved which are critical to the operation of the unit. Where necessary, booster pumps are provided to insure adequate water pressure.

Mechanical Design. Mechanical design considerations of water supply, physical arrangement of exchangers, and their construction are significant factors in preventing future corrosion problems. The following practices are recognized in order that maximum service life of exchangers may be realized.

1. *Water Supply.* a. Adequate screening is generally provided to prevent seaweed, shells, stones, etc. from entering the cooling water system. Frequently, additional screens of smaller (1/8 to 3/16 in.) mesh are provided in the smaller sized unit supply lines to reduce to a minimum entrained solids that may plug or damage exchangers.

b. Facilities are provided for intermittent chlorine injection at the entrance of the water to the system to kill algae and other forms of marine growth that exist in many waters used for one-through cooling systems. For closed systems using recirculated fresh water, inhibitors such as chromate are used to minimize scale formation and depositions caused by dissolved iron. Acid injection is also used in some instances for satisfactory pH control.

2. *Arrangement of Exchangers.* Exchanger layout can be a significant factor with respect to service life. During the "plot plan" stage of mechanical design, exchangers are arranged to allow ample clearance for bundle withdrawal and accessways for mobile equipment and maintenance crews. Such an arrangement is conducive to efficient and adequate inspection and maintenance, therefore a contributing factor in lessening the possibilities of corrosion troubles and unscheduled shut-downs.

3. *Construction.* For satisfactory construction of an exchanger the mechanical design features listed below are specified to foster streamlined flow and high efficiency as well as other desirable characteristics. Adherence has prevented severe corrosion difficulties from occurring.

a. Flaring (at an angle of at least

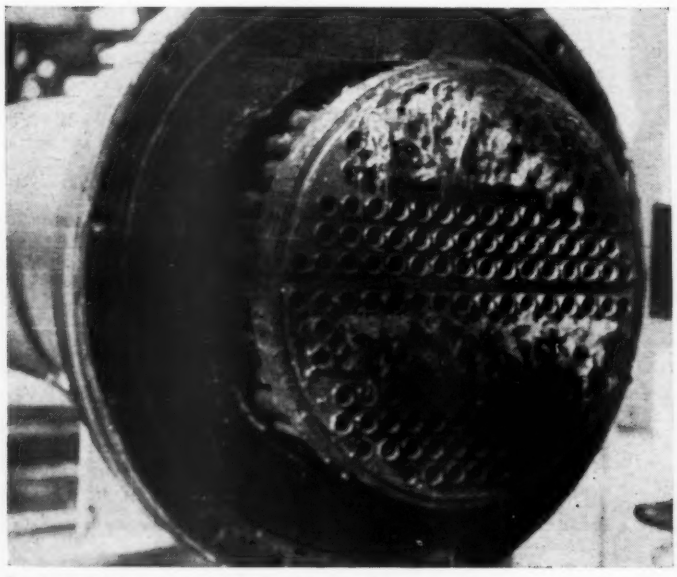

FIG. 3. Tube sheet fouled with marine growth.

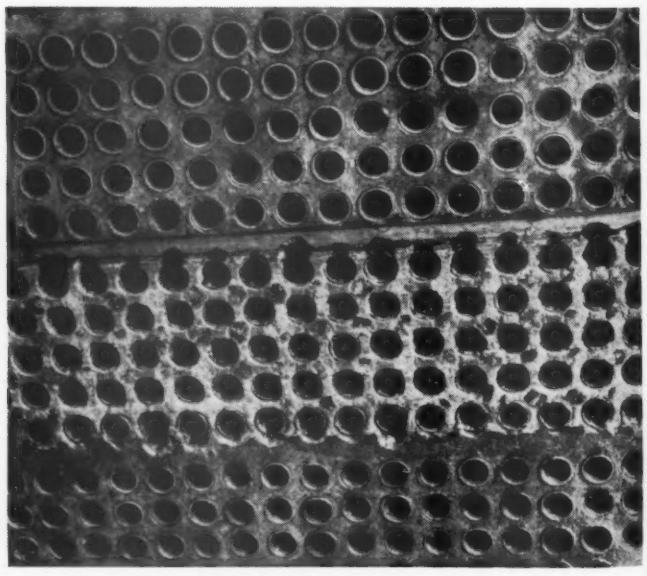

FIG. 4. Tube sheet deterioration.

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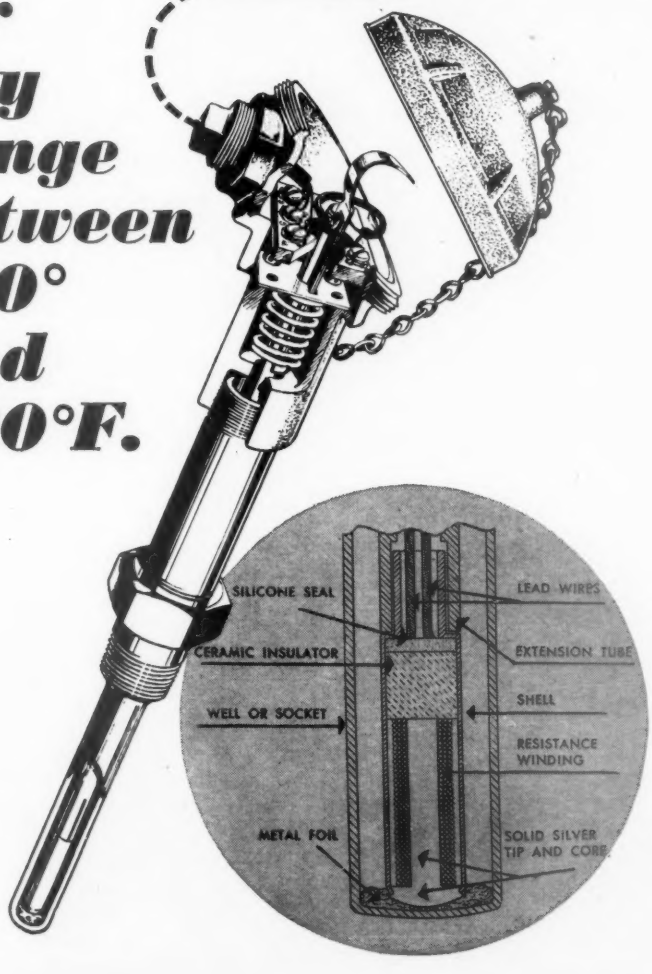

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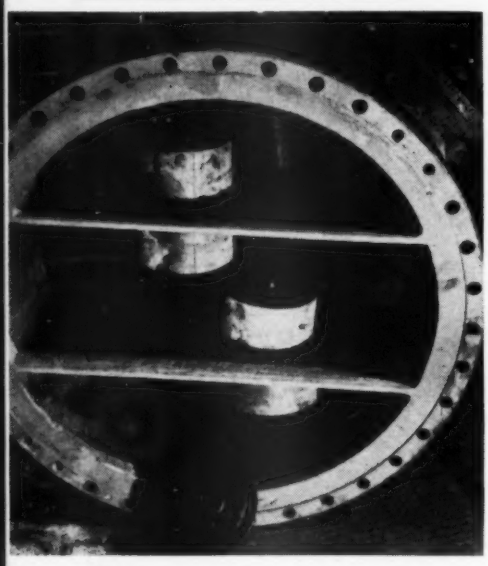


FIG. 5. Galvanic anode installation in channel.

FIG. 6. Galvanic anode installation in floating tube sheet cover.

15 deg) of the tube ends facilitates streamlined flow thereby lessening turbulence and deterioration of the tube ends.

b. Adequate crossover area in the channel and floating tube sheet cover is provided. This area is of vital significance in obtaining satisfactory corrosion free service life. Specifically, the crossover area should be at least 25 per cent greater than the area of the larger of the two adjacent tube passes, particularly in salt water service.

c. Sufficient baffling is provided to assure adequate support of the tubes along their length, thus avoiding stressed areas. Recommended maximum unsupported lengths are 52 and 60 inch for ¾ and 1 in. O.D. tubes, respectively.

Construction Materials. For the satisfactory service life of an exchanger, proper construction materials are believed to be paramount to other design factors. Materials must be resistant to numerous conditions which their juxtaposition makes even more difficult. Corrosive environments include not only many types of water but also, for some parts of the exchanger, various media which are to be cooled or condensed.

As this complexity has a considerable effect on the selection of materials, materials need be chosen with care and each exchanger considered separately. As water conditions for the most part are the primary factors, however, the materials given in Table 2 are those currently specified.

Because of cost or other factors, Monel, stainless steels, and aluminum alloys are seldom specified in initial design. Their use, however, is discussed later in the article. The comparative costs of tubes of various materials are shown in Table 3.

The materials need be selected with common sense also if corrosion difficulties are to be avoided. As the tubes are most critical to satisfactory exchanger life, the effect of the materials selected for other parts of the exchanger on the tubes is given every consideration.

TABLE 3. Comparative costs of tubes of various materials.*

(U. S. Manufacturers)

Material	Tube OD and BWG	Cost per linear foot
Aluminum (3S-H14)	¾ in.—16	$0.10
Aluminum (3S-H14)	1 in.—16	0.13
Carbon steel (welded)	1 in.—16	0.13
Carbon steel (seamless)	1 in.—16	0.16
Inhibited Admiralty	¾ in.—16	0.31
Aluminum brass	¾ in.—16	0.32
Aluminum bronze	¾ in.—16	0.34
Cupronickel (90/10)	¾ in.—16	0.40
Inhibited Admiralty	1 in.—16	0.44
Cupronickel (70/30)	¾ in.—16	0.47
Bi-metallic, steel, and Admiralty	1 in.—14	0.72
Monel	¾ in.—16	0.81
Stainless 316, welded	¾ in.—16	0.96
Stainless 316, welded	1 in.—16	1.20
Stainless 316, seamless	¾ in.—16	1.32

(* New York Costs as of March 1, 1954 on about equa[1] quantities)

A cardinal rule is applied here whereby large areas of materials significantly cathodic or anodic to the tube material are avoided. The use of Naval brass tube sheets with Admiralty tubes is generally satisfactory as the galvanic potential between them as indicated in Table 4 is not of great magnitude.

In some salt water services, however, even a small difference in potential has stimulated severe corrosion of the anodic Naval brass. The severe corrosion of the tube sheet shown in Fig. 4 is partially attributed to this galvanic effect. In fresh water services little difficulty in this respect is encountered.

In practically all water services, sacrificial anodes of magnesium, zinc, or steel are installed and in most instances are giving saisfactory protection. In salt water service, channels and floating heads are generally lined with lead or neoprene and therefore these anodes, particularly those of steel, afford good protection to gasket surfaces, tube sheets, and tube ends. They also insure against corrosion at possible voids in the lining.

In fresh water services, magnesium anodes installed as shown in Figs. 5 and 6 are particularly satisfactory in retarding if not preventing pitting of the steel or graphitization of the iron channels while affording protection to tube sheets and tube ends.

In addition to selection of resistant materials and use of anodes, corrosion allowances up to one-quarter inch are specified for bare metal surfaces, except tubes, depending upon the corrosion rate anticipated. A minimum of 1/16 in. corrosion allowance generally is provided on metal surfaces covered by non-metallic lining materials.

TABLE 4. Galvanic series of some materials in flowing sea water.[2]

Material	Potential*
Anodic (corroded) end	
Magnesium	1.51
Zinc	1.03
Alclad 3S-H	0.94
Aluminum 3S-H	0.79
Cast iron	0.61
Carbon steel	0.61
Type 304 (active)	0.53
Lead (estimated)	0.50
Naval brass (tobin bronze)	0.40
Copper	0.36
Red brass	0.33
Aluminum brass	0.32
Composition G bronze	0.31
Admiralty (Inhibited)	0.29
90-10 Cu-Ni (0.8 Fe)	0.28
70-30 Cu-Ni (0.47 Fe)	0.25
Type 316 (active)	0.18
Type 304 (passive)	0.084
Monel	0.075
Type 316 (passive)	0.05
Cathodic (protected) end	

* Steady potential (volts) negative to calomel half-cell Water velocity 13 fps.

Procurement. The procurement of exchangers, following their design, is indeed a complex and critical task. Aside from the many items involved, there are also numerous manufacturers and suppliers to be considered. During this stage there can occur some specific practices that may cause corrosion difficulties of some magnitude later on.

It is recognized that at times considerable price and delivery advantages are available by accepting standard designs of manufacturers in lieu of an

original design. At times, however, there is too little consideration given to the possibilities of future corrosion difficulties which may result from this procedure.

Initial cost savings and other possible gains from substitutions can be rapidly offset by maintenance and unscheduled shut-downs, the cost of which may be many times the initial savings. Substitute materials also are often necessary and justified but should be given even more careful consideration than the originally specified material to be assured that they do not impose reduced service life on the exchanger.

Fabrication. Reliance on manufacturers of materials and exchangers generally is necessary and justifiable. As exchangers, however, in most cases, are delivered to the refinery completely assembled and sometimes tested and ready for operation, undesirable conditions that may have been overlooked during fabrication go undetected. Some recommended fabrication procedures and conditions which affect service life are listed.

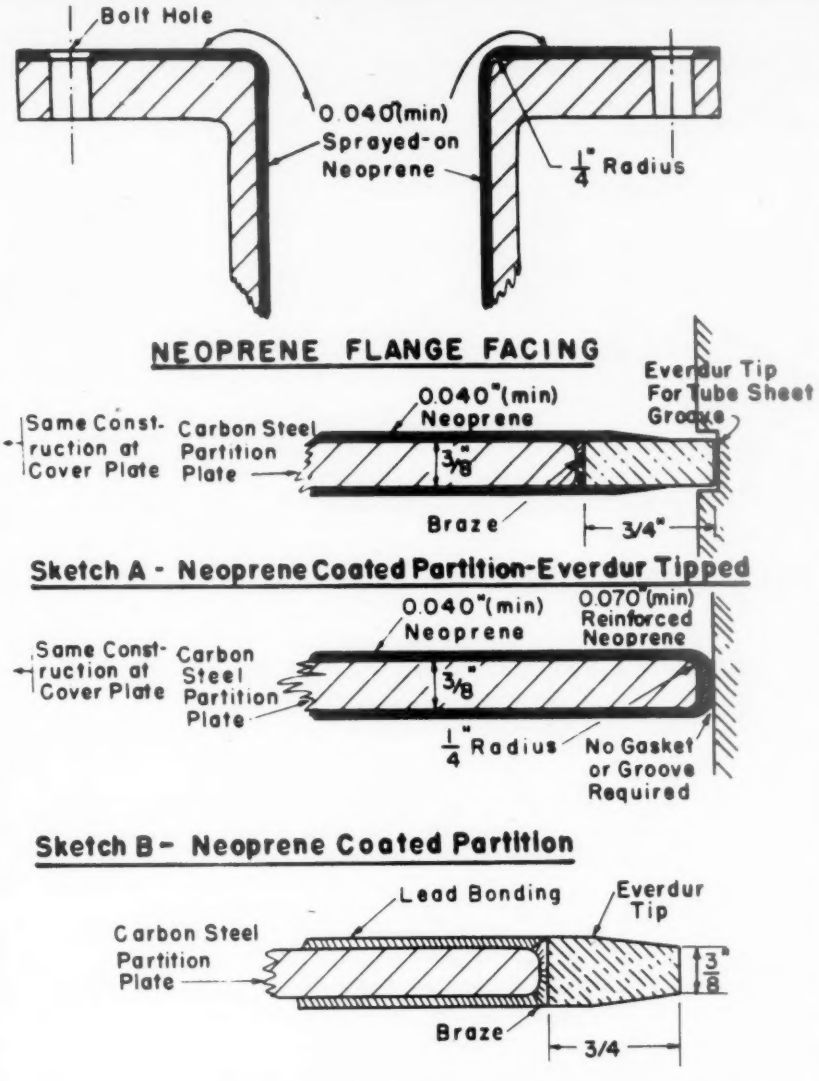
1. Homogeneous material, especially for tubes and tube sheets, is essential. Impurities or slight local variations in composition can cause severe difficulties such as plug-type dezincification and galvanic corrosion. Alloys not susceptible to these phenomena will still corrode rapidly at points of local contamination.

2. Copper alloy tubes should not contain residual stresses, therefore stress relieving is desirable. A dead-soft anneal impairs the corrosion resistance of the material whereas a moderate anneal will relieve all residual stresses and allow satisfactory rolling and flaring into tube sheets. Special anneal of the tube ends is of questionable value. A uniformly stress relieved tube of intermediate hardness is to be preferred because it imparts uniform corrosion resistance; transition areas between parts of a tube with different temper enhance stress concentration.

Assembly. During assembly of an exchanger, as during other stages previously discussed, numerous apparently insignificant things can happen that can be the cause of considerable losses from corrosion after the exchanger is placed in service.

1. Tubes should be protected from damage or other inclement conditions that can cause corrosion until they are installed, by keeping them in their original shipping boxes or similar containers in covered storage facilities.

2. Rough handling of tubes during assembly of bundles and unskilled manipulation of bundles during installation should be kept to an absolute minimum if not altogether avoidable.



Dents, scratches, scoring, bends, grooves, or strain on tubes may only be considered superficial but these areas form a nucleus for stress concentration. During operation even mildly corrosive conditions will cause stress corrosion or season cracking at these areas, leading to early failure.

3. Before buttoning up an exchanger for shipment or installation, every precaution should be taken to assure that debris, machining scraps, and other extraneous material have been thoroughly and completely removed. Such items can cause accelerated penetration during operation.

Operation. Operating conditions more severe than anticipated during design can offset many of the efforts expended in preceding stages aimed at preventing corrosion and attendant difficulties. An operator's full efforts and attention are necessary to maintain steady, smooth flow of the unit and obtain product quality. Likewise, adequate control of cooling water is significant to the continued satisfactory operation of a unit.

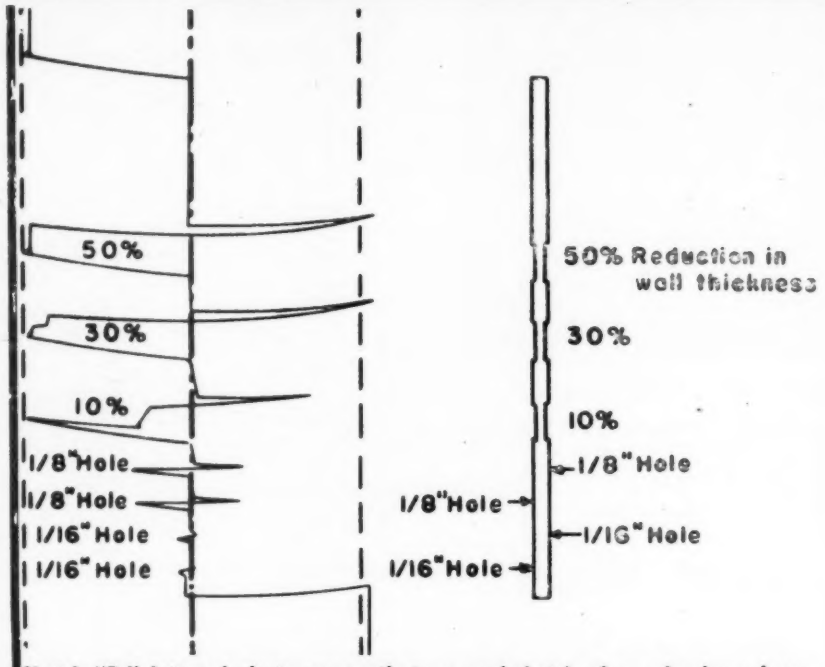
Where proper cooling water control is not practiced, full impetus in extending service life of exchangers cannot be realized. Numerous practices during operation have contributed toward the decrease in corrosion of exchangers.

1. Full flow of water to all tubes is maintained to every possible extent and the water outlet temperature controlled within limitations.

2. Water strainers in unit supply lines are provided where necessary and cleaned frequently to avoid excessive pressure drop that can rob an exchanger of needed water.

3. The presence of a vacuum or syphoning condition on the water side of an exchanger is detrimental to materials and is avoided by proper supply and control of cooling water.

4. When a unit is shut down, all



Sketch "D." Internal electro-magnetic trace and sketch of an aluminum brass tube, ¾-in. OD x 18 SWG x 4 ft, showing artificial defects.

water, debris, etc. is removed by blowing with air or any other method that will do the job. Severe corrosion can occur during downtime, particularly in copper alloy tubes, if water is left in the equipment.

Decomposition of marine growth, slime, anemones or other biological matter forms ammonia, which in the presence of any idle water can cause cracking of stressed areas in a matter of hours. Also during this period stagnant water or condensation can form incipient pits which upon start-up are the nuclei for accelerated penetration at these points.

Scheduled Turnaround. During exchanger design and other early stages it is difficult at times to justify expensive construction materials or foresee the degree of corrosion that will be encountered during operation. Therefore, despite the best intentions, problems still arise with corrosion and materials during a turnaround.

This period is of considerable significance to future service life of an exchanger, for it is during this period that possible deficiencies in design, procurement, etc., are corrected. It is needless to say, therefore, that a responsibility of considerable magnitude rests with the inspection and maintenance forces during a turnaround.

The practice of "preventive maintenance" has proved invaluable in reducing corrosion costs and attaining high service factor on operating units. It can be defined as the practice of inspecting and maintaining equipment in a manner calculated to reveal or prevent weaknesses or incipient failures at a time when simple remedial measures can often be taken thus eliminating the need for more costly repairs at a later date.

It has been estimated that of the total cost of corrosion in a refinery, about 70 to 80 per cent is attributed to maintenance during a turnaround as the result of corrosion. It is readily apparent, therefore, that during this period the greatest potential exists for progress in the mitigation of exchanger corrosion and reducing corrosion costs.

Principal preventive maintenance practices and non-destructive testing by inspection forces and cleaning of exchangers as part of routine maintenance.

1. *Inspection.* The function of the equipment inspection forces has been adequately covered in numerous papers previously published.[2] Its significance, however, is briefly reiterated in order to highlight its influence on corrosion prevention in exchangers.

For effective analysis of a corrosion problem, inspection of an exchanger is conducted as soon as possible after the exchanger is opened and before any work is performed that might disturb valuable corrosion evidence, scale deposits, general condition of the exchanger, etc.

To a great extent, the future service life of the exchanger rests on the thoroughness of the inspector's examination, the accurate analysis of his findings, and the explicitness of his recommendations. That this has been realized is evidenced by the increasingly longer intervals between shutdowns today.

Non-destructive test methods such as those discussed below are felt to be major contributing factors to longer unit runs.

Nondestructive test methods are generally those associated with the use of instruments and other measuring devices of numerous types as well as some basic tools. Among these are several that are particularly useful in examining exchangers for corrosion or other defects.

The magnetic particle inspection method for magnetic materials and the related method for non-magnetic materials using a fluorescent penetrant have proven of considerable value in detecting cracks and similar flaws in channels, tube sheets, floating head covers, etc.

Other techniques employing supersonic waves, radium, and magnetic fields have limited but, at times, valuable application. Tools such as depth gage, calipers, magnet, bug lights, dental mirrors, and magnifying glass are useful aids in the examination of materials and determining the causes for surface defects or deterioration found.

An instrument using the electromagnetic principle has shown considerable merit for the internal examination of non-magnetic exchanger tubes. Exchanger tubes, which are of small diameters, cannot be visually inspected internally with any degree of accuracy.

Often tubes are replaced unnecessarily because of the failure or corroded appearance of adjacent tubes. With experienced use of the electro-magnetic type instrument, an internal examination along the length of the tube gives a surprisingly accurate picture of the condition of the tube wall, as illustrated in Sketch D. On numerous occasions considerable savings have resulted from its use.

Tube bundles which were scheduled for complete retubing were first surveyed by this method, and it was determined that corrosion was principally localized in only one or two passes so that only this portion of the bundle had to be retubed. It is only by regular use of this instrument that a proper estimation of its values for any particular problem can be fully appreciated.

Through its use the state of tubes can be accurately interpreted and often in a way that is believed to be impossible by any other method known. It is to be emphasized, however, that any instrument is most valuable when used as an additional aid to diagnosis, rather than something to replace existing methods.

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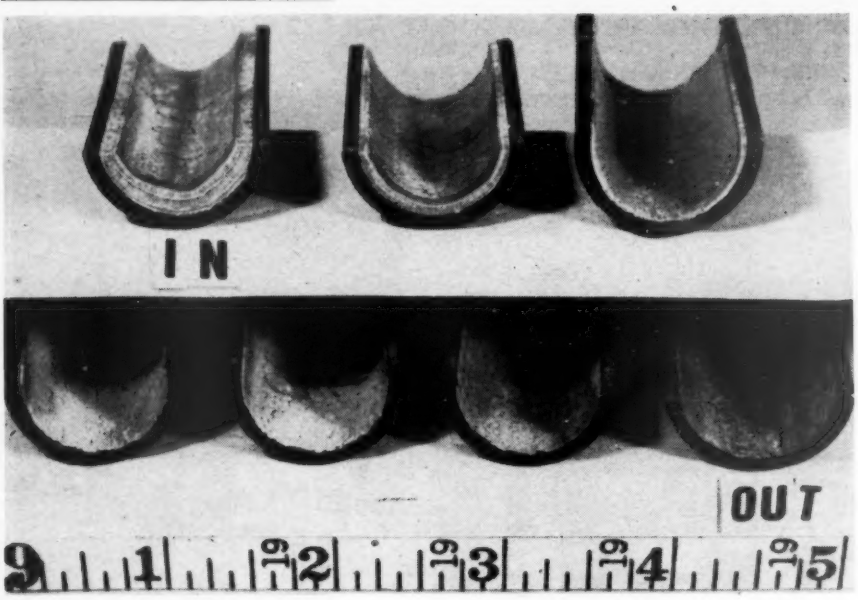

FIG. 7. Scale deposition in tube.

maintenance performed are the heart of an efficient system. These form the basis for an intelligent analysis of a corrosion problem, particularly a recurring one. They also provide the data necessary to justify material substitutions or design changes for extending service life or improving efficiency of an exchanger.

The value of a thorough inspection and competent analysis of difficulties can be short-lived if equally thorough and competent records are not kept for future reference and correlation.

2. *Maintenance.* Effective maintenance as well as a coordinated and organized maintenance program have been highly effective in reducing corrosion costs while increasing operating service factor.

During the turnaround, cleaning of exchangers as a preventive maintenance procedure has proved significant. Numerous cleaning techniques have been effective depending upon the circumstances. When correctly employed they avert corrosion difficulties by removing deposits and other solids that form the nuclei for numerous forms of attack previously discussed.

The three methods commonly used are chemical, mechanical, and water-blast cleaning. Each of these methods is capable of giving satisfactory results and their use varies from one refinery to another depending upon local factors.

a. **Chemical cleaning**[3] involves primarily the use of acid along with inhibitors, wetting agents and intensifiers. This method is particularly effective in removing algae, slime, scale, and similar fouling material from the tubes and other surfaces. Careful control during cleaning operations is required, however, to prevent metal loss.

b. **Mechanical cleaning** methods are somewhat severe on materials but with careful use no detrimental effects should result. The method used depends upon the characteristics of the equipment and the nature of the fouling material.

Methods widely used, and in order of increasing severity on equipment, are the air blast, water jet, steam jet, rodding, drilling, sandblast, and a combination of these methods. Excessive operating temperatures can cause heavy scale deposition in tubes as shown in Fig. 7.

Frequently these deposits are soft enough when the equipment is first opened up to be cleaned by one of the less severe methods. If allowed to harden by dehydration, however, as occurs in most cases, harsh cleaning methods such as drilling or sandblasting are required and frequent injury to the tubes results.

A method of blast cleaning[4] has been devised using spent catalyst from fluid catalytic crackers. This method has been of particular advantage in cleaning non-ferrous tubes which are often pitted by the sand blast method.

c. **Water-blast cleaning**[5] utilizes a high velocity stream of water and sand to remove deposits. This method is not usually required for cleaning of water side deposits. It can be effectively used to clean tube sheets and the inside of tubes, however, when less severe methods fail.

In addition to preventive maintenance there are numerous other maintenance measures carried out during a turnaround period which are dictated to a great extent by the severity of the conditions found in the exchanger.

Preventive Measures

There is no panacea for exchanger material failures in cooling water service, the reasons for such failures being manifold and complex. Each exchanger presents a different problem to some degree and requires independent investigation. This procedure if practiced will result in far better and more long lasting results in extending the service life of the equipment.

The following covers preventive measures used based on the conditions found to exist after a period of operation.

Water Supply. Some corrosion problems in exchangers are caused by trash, debris, etc., entering the equipment with the cooling water. Where such conditions as illustrated in Figs. 3 and 8 are revealed, immediate corrective steps are taken. This generally consists of installing screens.

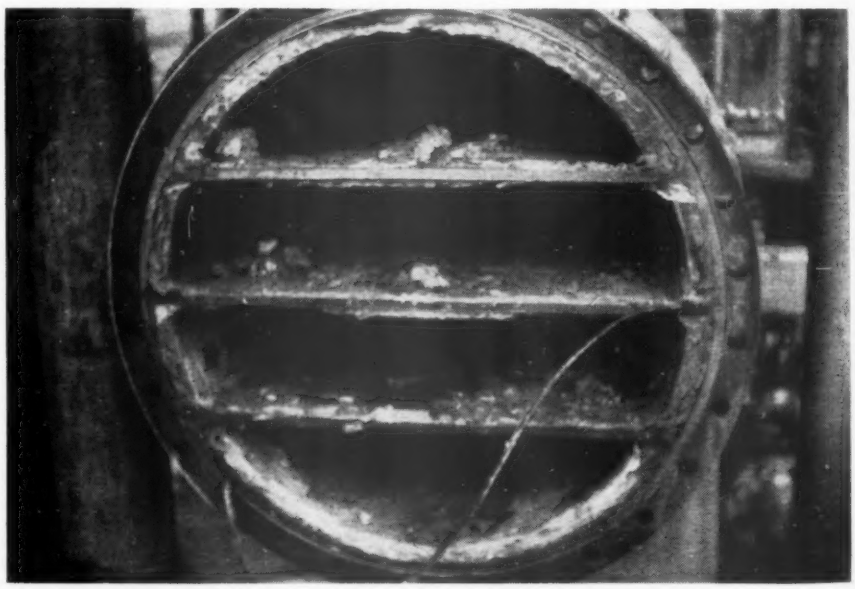

FIG. 8. Trash in the channel.

For small particles like sand and silt that are not readily removed by screening, a settling basin of one form or another is desirable and provided where conditions permit. Entrained solids are destructive to exchanger materials and are minimized to the greatest extent possible.

Water Treatment. The control of the corrosive potentialities of water by chemical treatment usually is practical and effective only in closed recirculating systems. In a once-through system chemical injection, except for chlorination, is too expensive and in most cases difficult to justify. Numerous treatments have been used, however, and, although results are variable because of localized and diverse water conditions, some are of proved value and briefly discussed as follows.

1. *Chlorination* is incorporated in the design of once-through salt cooling water systems. Indications are that continuous, rather than intermittent, chlorine injection gives most satisfactory results. In some cases continuous injection appears to be necessary for chlorination to be effective.

It has been confirmed[6] that some marine organisms such as barnacles can close up for long periods and thus avoid taking in any treated water during intermittent chlorination. Therefore, a continuous addition at a low residual concentration, e.g. 0.25 to 0.50 ppm, is indicated to be more effective than cyclic treatment at a much higher concentration.

This is further confirmed by the dense build-up of organisms in the water systems of some refineries that use intermittent injection.

2. *Inhibitors* have been quite successful in reducing corrosion and scaling of steel surfaces in cooling water equipment. A well water (Table 5) was readily and satisfactorily treated with a phosphate (sodium metaphosphate) to inhibit scale deposition and chlorine to prevent organic growth without the requirement of exacting control.

A river water (Table 5) caused serious corrosion problems until treated. The river water was treated with an organic chromium inhibitor at a rate of about 50 ppm and corrosion tests later indicated a reduction of about 88 per cent in corrosion rate. It is currently being used in at least 5 major fresh water cooling systems and more extensive use is planned.

TABLE 5. Typical analysis of well and river water.

	Well water (ppm)	River water
SiO_2	24.6	12.1
Fe_2O_3	2.1	5.1
Ca	6.8	17.2
Mg	2.2	2.7
Na+K	199.5	38.4
SO_4	10.0	—
Cl	89.0	56.5
HCO_3	400	69.2
Dissolved solids	734.2	208.4
Hardness as Ca CO_3	22.5	53.8
Suspended solids	—	66.9
pH	8.1-8.5	7.5

TABLE 6. Materials* for coolers and condensers. Recommended future practice.

	Salt water service	Fresh water service	Remarks
Tubes†	Aluminum brass (1) (4) 90-10 Cupronickel (0.8 Fe) (2)	Inhibited Admiralty	(1) General refinery service except Admiralty used where experience shows it to give at least five years satisfactory service.
Tube sheets	Carbon steel protected on the water side with neoprene, 40 mils (min.) thickness	Same as for salt water	(2) For use where water temperature, velocity, impingement or contamininations are too severe for aluminum brass.
Channel	Carbon steel or cast iron, neoprene lined, 40 mils (min.) thickness	Carbon steel or cast iron	(3) No lining required when full face steel anode is used.
Channel cover	Rolled or forged steel, neoprene lined same as channel (3)	Rolled or forged steel	(4) Tube ends lined with sprayed neoprene 10 to 15 mils thick for a depth of 5 in. maximum where experience has shown need for tube end protection.
Channel partition plates	Same as channel, neoprene applied per Sketch B	Same as for channel	(5) Specification for new equipment except where local preference or conditions dictate otherwise.
Floating tube sheet cover	Carbon steel or cast iron, neoprene lined on water side same as channel.	Same as for channel	
Gaskets	None required in water side joints.	Asbestos—channel side Nonferrous metal jacketed asbestos on floating end cover.	
Anodes	None required	None required	

* Exposed to cooling water
† Bi-metallic tubes of non-ferrous inner wall and steel outer wall for special services.

The introduction of the chromate ion into water has long been used to prevent corrosion. It is used generally in circulating systems where relatively little make-up water is required. It is particularly useful in clearing water of turbidity and depositions caused by dissolved iron.

Sodium chromate is preferred over the bichromate because it does not deliquesce nor does it require the addition of caustic to maintain an alkaline pH. The normal procedure in using chromates in closed systems is to obtain a high initial concentration to insure the formation of a homogeneous passivating film on the metal surface.

An operating range of 250-500 ppm is generally used. Its use has resulted in an increase of efficiency and decreased corrosion of exchangers as well as other equipment.

Where tuberculation in tubes and elsewhere is a problem and costly water treating may be justified, acid injection is used. The injection of sulfuric acid to the water until a pH of six and a half or seven is continuously maintained changes localized tuberculation attack to a mild uniform type surface corrosion extending tube service life considerably.

Materials. Corrosion experienced after a period of operation is being satisfactorily reduced and service life of exchangers greatly extended by the judicious use of materials during maintenance periods for replacements or linings. The proper material selection is based on an economic balance considering initial cost, probable life, cost and availability of replacement or repair materials, ease and speed of field repairs, and frequency of maintenance required. The following summarizes the general results and gives conclusions regarding various materials which have been used to prevent corrosion in cooling water service. Table 6 reflects materials for "Recommended Future Practice" which for the most part are based on the correlation of experiences.

Whereas Monel, 70-30 cupronickel, aluminum, and stainless steel tubes give satisfactory service in salt water exchangers, their higher cost or other factors limit their use. Although relatively few experiences can be cited, it appears that 90-10 cupronickel with 0.8 per cent Fe can give good service where velocity, degree of water contamination, and water temperatures are higher than suitable for either Admiralty or aluminum brass. Aluminum brass and 90-10 cupronickel tubes will satisfactorily and economically handle most requirements in cooler or condenser service where salt or contaminated water is used.

Naval brass tube sheets have been commonly used for many years in cooling water service and have given satisfactory service; in some cases upwards of 10 years life prevails. As Naval brass is anodic to most materials used for tubes, however, there are refineries where severe corrosion of the Naval brass has taken place probably because of local water conditions. In many cases such difficulties cannot be predicted. To avoid tube sheet corrosion, a coating of sprayed-on neoprene is now frequently being used.

Initial successes indicate that steel tube sheets protected with neoprene can be an economical and satisfactory substitute for Naval brass and galvanic effects that may be detrimental to either the tube sheets or tube ends can thus be avoided. Steel tube sheets clad with Monel or brass also are giving good service, although in limited use.

Care is necessary in rolling tubes into metal clad tube sheets to assure tightness so that water does not get past the cladding and corrode the steel

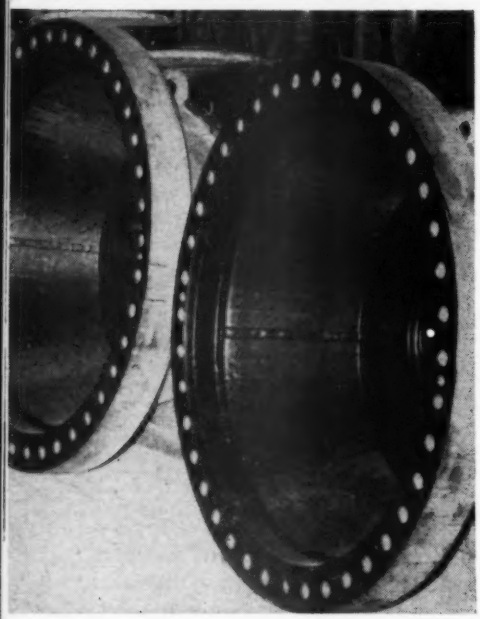

FIG. 9. Water box with neoprene lining continued over gasket surfaces.

FIG. 10. Thermometer in water outlet line.

tube sheet. Metal clad tube sheets also are more expensive than neoprene coated ones and they are therefore not frequently justified.

For channels, many materials have been used with equally numerous and varied results. Ni-Resist gives good service but repairs are not always practical when cracks of graphitization occur. Likewise Monel is generally difficult to repair although long service can be obtained. Monel can present a strongly cathodic influence, however, on naval brass tube sheets and non-ferrous tubes and thereby promote corrosion. Metallizing with Monel, zinc and aluminum has been generally unsuccessful.

Sheet rubber linings on steel give inconsistent results with service life ranging from 8 weeks to 8 years. Generally poor bond of the rubber to the metal is responsible in most cases of early failure. Sheet rubber also requires special design features which can be costly and can offset possible advantages.

Vinyls and other paint coatings, applied according to manufacturer's specificatons, have shown perhaps one year's service but are not reliable. A baked porcelain enamel coating shows promise and with improved application better service may result. Flame-sprayed polyethylene has excellent water resistance but fails because of poor adhesion, similar to sheet rubber.

Baked-on phenolic resin coatings give 1 to 2 years protection and have good bond to metal. The coating is brittle, however, and requires considerable care in handling. As local repairs are practically impossible, this coating is impractical for exchanger service. Brass linings have been satisfactory but considerably limited in use because of high cost. The most promising lining is neoprene.

As a lining, liquid neoprene is sprayed-on to a minimum thickness of 40 mils (0.040 in.) forming a tough, resilient, and impervious barrier to corrosion and erosion by cooling water. Over flange faces such as illustrated in Fig. 9, the neoprene is sufficient to act as a gasket in most instances.

As protection for tube sheets and tube ends the neoprene is spray applied as a monolithic layer on the sheets (40 mils minimum thickness) and into the tubes (10-15 mils thick) for a distance of from 3 to 8 in. and feathered to give smooth flow of water.

The optimism and successes with neoprene thus far are predicated on technique in application with considerable emphasis on the bonding agent used as neoprene itself does not adhere satisfactorily to metals. For severe conditions as experienced in industrial cooling water services, the use of neoprene should be based on known experiences or preceded by tests in actual service.

Comparative costs of neoprene and other lining materials used are given in Table 7.

TABLE 7. Comparative costs* of linings for coolers and condensers.

	Cost per square foot
Gunite (¾ in. thick and reinforced)	$ 2.00
Sprayed-on neoprene (0.040 in. thick)	$ 3.75
Sheet lead (12-5/16 in. thick)	$ 6.00
Bonded lead (3/16 in. thick)	$14.00
Monel (⅛ in. thick)	$20.00
Type 316 alloy steel (⅛ in. thick)	$22.00
Cast brass, machined fit	$25.00

* Estimate based on steel channel, 30 in. diameter, 18 in. deep, two pass.

Materials for floating head covers have been somewhat more restricted to carbon steel or cast iron lined with neoprene or lead because of exposure to both shell and tube side media. Where metal temperature can exceed 200 F, during normal operation (infrequent) cast brass is used.

Cathodic Protection. Water side corrosion of channels, heads and tube sheets, and other surfaces can be insidious, such as crevice corrosion at gasket surfaces. Steel is subjected to severe pitting whereas cast iron parts are highly susceptible to graphitization such as shown in Fig. 2.

Cathodic protection is one method that is satisfactory to prevent these and other types of metal deterioration commonly experienced. Currents for cathodic protection of exchanger surfaces may be obtained by (1) externally supplied direct currents or (2) galvanic anodes.

TABLE 8. Composition of materials.

(Mentioned in Text)

Admiralty (inhibited)	71 Cu, 27.95 Zn, 1.0 Sn, 0.05 Sb, As or P
Aluminum Brass	76 Cu, 21.93 Zn, 2 Al, 0.04 As, 0.03 Pb
Composition G bronze	88 Cu, 2 Zn, 10 Sn
Cuprionickel—90/10	89 Cu, 9.81 Ni, 0.19 Mn, 0.8 Fe, 0.20 Zn
Cupronickel—70/30	69.92 Cu, 30.16 Ni, 0.45 Mn, 0.47 Fe
Everdur	95.85 Cu, 3.0 Si, 1.0 Mn, 0.15 Fe
Monel	30 Cu, 67 Ni, 1.4 Fe, 1.0 Mn, 0.1 Si, 0.15 C
Naval brass	60 Cu, 39.25 Zn, 0.75 Sn
Red brass	85 Cu, 15 Zn
Type 304 alloy steel	18 Cr, 8 Ni, Bal. Fe

The system utilizing an external source of current consists of carbon anodes (insulated from the channel) insulated leads, and a direct current generator or transformer and rectifier. Advantage of this system is the positive protection that is afforded to all tube ends, tube sheets, and adjacent equipment parts.

Disadvantages are its high cost, the intricate installation, the near impos-

sibility of protecting both tube sheets in tube bundles with floating ends, and the possibility of sparking in fire-hazardous areas. Maintenance costs also are high. Development work on this type system continues, however, in an endeavor to overcome some of the disadvantages.

The use of galvanic action between the more noble (cathodic) metal to be protected and a dissimilar (less noble) metal that is sacrificial (anodic) has proved to be more practical although lacking the control and advantage of the method previously discussed.

In the case of exchangers handling a corrosive and electrolytic medium such as water, the latter method is usually the less expensive and more readily installed of the two. This involves the installation of sacrificial anodes that undergo destructive corrosion and which, for this reason, must be of relatively inexpensive material.

Magnesium has been used extensively as anode material because of its ability to maintain high current output during its entire life as an anode, its non-fouling properties, and also because it is relatively inexpensive. Mild steel and high purity zinc anodes are also performing satisfactorily and economically where applicable, and in those cases where longer life at less current output offers adequate protection, at less cost. The installation of either magnesium or zinc anodes is similar in design and shown in Figs. 5 and 6.

Numerous refineries continually report excellent results with anode installations of this type. In these cases uniform wastage of each anode is evident as well as a thin but yet protective film on the exposed surface of the equipment. Such successes are more readily obtained in refineries using fresh water.

Where salt water is used, magnesium anode wastage is too rapid and uneven for either adequate protection or long anode life. The successful use of magnesium anodes for a three year period in fresh water service at one refinery resulted in:

a. Greatly reduced repairs to gasket surfaces,
b. No increase in depth or existing pits,
c. Considerably lessened tube sheet corrosion,
d. Economical and attractive protection from the standpoint of low cost, and
e. Specifying and equipping all new exchangers in cooling water with magnesium anodes before being placed in service.

After many years of experimental work in the galvanic protection of nonferrous tubes and tube sheets, the Aruba Refinery (Lago Oil and Transport Company, Ltd.) has developed the full-face steel sacrificial anode. This refinery, like some others, uses lead linings in channels and floating tube sheet covers. A steel anodes full potential, therefore, can be directed to protecting the tube sheets, tube ends and gasket surfaces.

Considerable experience with these anodes has shown them to afford a high degree of protection, be effective for the duration of a run, and provide a more tenacious and impervious protective film on the non-ferrous surfaces than previously used magnesium or zinc anodes. Also they are economical and easy to install and replace. It is believed that this anode may prove to be a significant contribution to reducing corrosion of equipment in salt cooling water service.

It is to be cautioned that anodes can be destroyed rapidly if acid cleaning of the exchangers is practiced. This cleaning method, therefore, should be avoided or the cleaning performed only after the anodes have been removed.

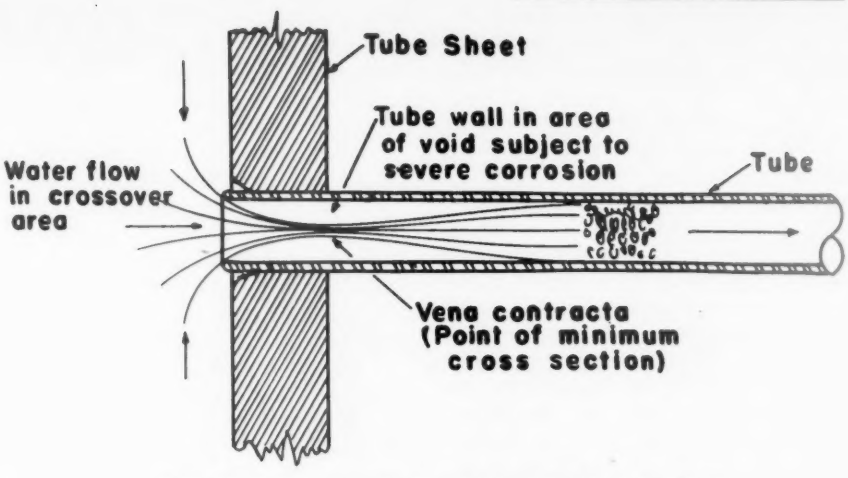
Tube Sheet
Tube wall in area of void subject to severe corrosion
Tube
Water flow in crossover area
Vena contracta (Point of minimum cross section)

FIG. 11. Vena contracta in tube installed in tube sheet.

Design Changes. Frequently during shutdown periods the corrosion experienced suggests design changes rather than continued material replacement. Often, too, these design changes are relatively inexpensive to accomplish and result in considerable savings during future maintenance periods. There follows a brief discussion of several such changes that can assist in overcoming corrosion difficulties.

1. *Temperature Control.* The water outlet temperature is of such significance in the mitigation of corrosion that all possible inducements for its control are promoted. On existing equipment a temperature indicator can readily be installed during a shutdown if not provided for during design. A clearly visible temperature, such as obtained by the indicator shown in Fig. 10, facilitates water control.

2. *Increased cross-over area.* Tube end erosion-corrosion, of serious proportions in numerous refineries, is attributed to a large extent to inadequate cross-over area in the floating tube sheet cover between adjacent passes. This construction causes turbulence and sharp direction changes in water flow neither of which is conducive to satisfactory tube or tube sheet life.

A flow, characteristic of "vena contracta" such as illustrated in Fig. 11, can be formed that sets up highly destructive corrosion and erosion actions. Rapid failure of tubes occurs in this area. It is generally confirmed that liberal design of exchangers in cooling water service would decrease maintenance costs during their life by an amount considerably greater than the initial incremental cost. The cross-over area is designed for streamlined flow. To obtain this desired area in existing, older units, where corrosion distress is in evidence, two methods are used.

a. The head is replaced with a larger one having the minimum cross-over area required, or
b. A spool insert, of sufficient depth to increase the area to that desired, is locally fabricated and installed between the tube sheet and existing floating head.

Which of these procedures is used (on the floating end) depends upon the amount of space available in order that free movement of the bundle during service is not restricted. Exchanger alterations of this nature have definitely proved of value in reducing tube-end deterioration.

Other Methods:

1. Tube End Inserts. As previously discussed, high velocity and turbulence frequently cause deterioration of tube ends by erosion and impingement while the remainder of the tube is only mildly affected. Even though the cause is not eliminated, the service life of the tubes can be extended considerably by the installation of tube-end protectors (inserts).

Satisfactory results are being obtained with inserts of metal, neoprene, plastics, and natural rubber. Metallic inserts with fiber sleeves have not been entirely satisfactory. Inserts of nylon are being tested and appear to have considerable promise.

Inserts about three and one-half inches long appear to be optimum. Greater lengths are difficult to install and seldom necessary. Although the life of tubes has been doubled in some instances with the use of inserts, they should be considered as a patch-up material for repairing or preventing the results of an undesirable condition. Changing conditions to prevent the tube-end erosion will be more economical in certain cases than indiscriminate installation of inserts.

It is a general refinery consensus that tube end inserts are not necessary in well designed equipment in which turbulence and excessively high velocity of the coolant are absent. Their use should be restricted to existing equipment where conditions show that the service life of the tubes can be improved.

2. Storage and Protection of Bundles. All refineries carry large inventories of tubes and other materials for ready replacement during turnarounds.

In many instances, complete spare bundles for critical exchangers are held in standby so that speedy replacements can be made and shutdown time proportionately reduced. For safety and efficiency, bundles should be protected in storage because serious deterioration can occur during this period making them unfit for service when needed. Aside from providing dry and covered storage, bundles are frequently protected further by protective coatings. There follows mention of several which, applied by brush, spray or dip, have been satisfactorily used.

a. Bundles are dipped in a vat containing micro-crystalline wax at 225-250 F for about 45 min. This treatment is repeated about once a year. Since the wax coating is only about 1 mil thick (or about 1 gal for 1600 sq ft of surface) it is not durable for outdoor storage in a marine atmosphere. This wax does not have to be removed prior to placing the bundle in service. The film of wax has shown no noticeable affect on heat transfer in water service nor contamination of hydrocarbons.

b. A heavy petrolatum dip at 185 F is also used satisfactorily. Removal of this film by naphtha solvent, however, is desirable before placing the bundle in service. Protection for about one year or more outdoors can be expected.

c. A clear varnish rust preventive gives a hard-drying film that enables easier handling. This type film would not be expected to last for more than about six months, however. It is removed by an alkali such as caustic or trisodium phosphate.

Economic Incentive

The annual corrosion losses in the petroleum industry are enormous. Preliminary estimates by the API Subcommittee on Corrosion indicate the Petroleum Industry's corrosion bill to be about $280,000,000 annually in this country. Similarly, Jersey Standard's annual losses have been roughly estimated at about $90,000,000 worldwide and $33,000,000 domestic. Astounding as it may sound, a large refinery (200,000 bbl per day) can suffer corrosion losses to the extent of $7 and $8,000,000 a year. It is no wonder then that a tremendous incentive exists to do something about this costly wastage of materials.

A large share of these losses can be attributed directly to exchanger corrosion. Why? Firstly, there are many exchangers in a modern refinery. Secondly, an exchanger is a complex, therefore, costly piece of equipment. Thirdly, many exchangers are exposed to one of the most corrosive environments in a refinery—water. Fourthly, tubes, tube sheets, and floating tube sheet covers can be corroded from both sides. Therefore, repairs due to corrosion are great and can incur considerable expense.

Past reports indicate that annual refinery heat exchanger maintenance costs have been as high as $400,000. It is conservatively established that upwards of 50 per cent of this cost will be eliminated by the currently used corrosion preventive procedures discussed herein.

Conclusions

It is concluded by this study that the magnitude of corrosion is being materially reduced by the extensive use of existing methods and materials. Continued progress necessitates the utmost and hearty cooperation of manufacturer and user alike, however. Their joint endeavor should be directed towards exchanger designs that are highly efficient and functional yet not creative of conditions conducive to corrosion.

It can be concluded also that development of new materials and methods to resist attack by cooling water should continue. Also, a more widespread understanding of the fundamentals of corrosion phenomena together with more individual and accurate diagnosis of problems should be stimulated to the greatest extent possible.

Acknowledgment

The author is grateful to his associates in Esso engineering department and friends in affiliated refineries for their comments and help during the preparation of this paper. Of significant assistance were the numerous contributions by the Lago Oil and Transport Company, Ltd., resulting from many years of work and study by their Aruba refinery in the mitigation of corrosion by cooling water.

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Biggest Gas Deal

What may be the biggest gas deal in history was completed in Tulsa, Oklahoma, in mid-December, resulting in assurances of adequate gas supplies not only for the Pacific Northwest country, but also the nine states west of the Rocky Mountain range. The move also cleared the way for construction of nearly 3000 miles of gas line in the coming months.

Participants in the deal are Pacific Northwest Pipe Line Corporation, Westcoast Transmission Company, Ltd., and El Paso Natural Gas Company. The agreement will provide for bringing Canadian gas to the Pacific Northwest, insure adequate supplies for California, and formation of a grid of gas line to most major consuming areas.

Total cost of the project will be near $400,000,000. Included are the 1466-mile Pacific Northwest Pipe Line from the San Juan Basin to Bellingham, Washington; West Coast Transmission's 650-mile line from the Peace River Basin to the U.S. Border, and a 370-mile line from Mountain Home Idaho to Reno, Nevada, planned by El Paso Natural, which will later carry gas to California gas companies for delivery at the Nevada-California border.

Colorado Interstate Gas Company will also proceed with a 365-mile line to carry gas from a Pacific Northwest line connection to markets in Colorado.

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Court Stay Asked

The third U.S. circuit court of appeals in Philadelphia has been asked by Panhandle Eastern Pipe Line Company to stay an FPC authorization given American Louisiana Pipe Line Company to build a $130,000,000 Louisiana to Michigan natural gas pipe line. The petition was directed against American Natural Gas Company, holding company of American Louisiana.

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$17 Million Program

Texas Gas Transmission Corporation has asked FPC approval for a $17,500,000 expansion program that would increase capacity 102,000,000 cu ft per day, add 190 miles of loop line—half of it 20 and 26-in., and add 22,600-hp to 7 of the present 21 stations, plus a new 4500-hp station at Riverton, Louisiana.

More 36-In. Pipe

Transcontinental Gas Pipe Line Corporation, first gas transmission company to lay 36-in. pipe, plans to add more of the "super-inch" line on a greater scale in 1955. The company's initial big pipe was laid this summer in Mississippi and Alabama *(see page D-51, Petroleum Engineer, October, 1954)*. The firm has asked the FPC to approve an $80,000,000 program that would start next year, for which the bulk expenditure would be for 36-in. loops, plus some 30 and 24-in. loop lines.

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Trans-Canada Extension

The Alberta conservation board has granted an extension of financing and construction deadlines to Trans-Canada Pipe Lines, Ltd., for its natural gas line from Alberta eastward. Trans-Canada was given from a delay from June 1 to June 30 to begin construction on the 2200-mile line. The board also extended from December 31 to April 30 the date for showing purchase and sales contracts. The extensions were sought as result of a delay in negotiations with the feeder company organized by the province.

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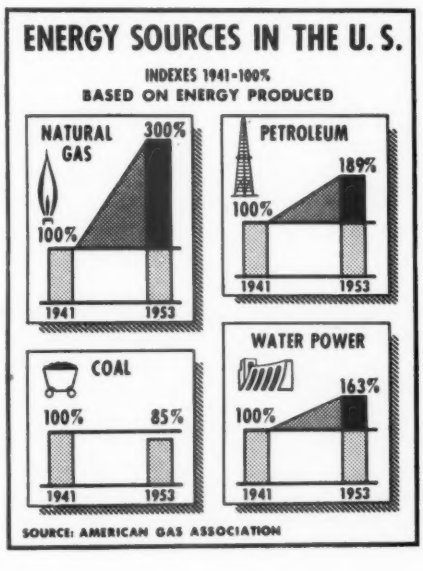
News Nuggets:

The combined system of the Portland and Montreal Pipe Line Companies has completed an expansion program that boosts capacity from 158,000 to 190,000 bbl per day. Four new pumping stations have been added on the 18-in. line for a total of eight. A parallel 12-in. will continue to operate with four stations.



Shell Pipe Line has completed and placed into operation a 35-mile, 12-in. in Montana between tank car loading facilities and the Pine and Cabin Creek fields. Crude is carried by railroad to Frannie, Wyoming, where it is delivered to the Platte Pipe Line for shipment to the Shell refinery at Wood River, Illinois.

Overland Pipeline Corporation, a South African firm, has asked South African government for permission to build 350-mile, $8,500,000 products pipe line. The line, which would compete with the government-owned railroad, is expected to have a rough time in getting authorization.

ICC reports for the third quarter showed a decline in movement of crude and petroleum products by pipe line. Traffic volume was down some 21,000,000 bbl and revenues down some $470,000, compared with second quarter figures. Compared to 1953, revenues were up $490,000 but traffic volume was down some 21,500,000 bbl.

Operation of a 230-mile microwave system, including one hop of 80-miles, has been begun by Colorado Interstate Gas Company. The system connects company headquarters with stations and fields in Oklahoma and Kansas. Channels are provided for both voice communication and remote control circuits.

Platte Pipe Line Company has applied to the Wyoming Public Service Commission for a permit to build an 8-mile, 6-in. crude line connecting Gebo field to a point near Chatham, Wyoming.

Transcontinental Gas Pipe Line Corporation has completed a $169,446,000 refinancing operation involving the entire first mortgage debt of the firm. The transaction gives the company $85,000,000 of new financing, including repayment of 1954 bank borrowings.

Cheyenne Valley Pipe Line Company has withdrawn its application to the Wyoming Public Service Commission for a permit to build a 118-mile, 10-in. line. The promoters of the line have reportedly decided to direct their activities towards a natural gasoline plant in the Weston and Niobrara counties area.

Standard Oil Company of Texas has been granted an ODM rapid tax write-off of 25 per cent of $3,643,500 construction cost on its 250-mile El Paso-Albuquerque products pipe line and 40 per cent of $506,500 for storage.

George L. Chapman, Wolverine attendant at Hammond, Indiana, transmits pipeline operations data to New York over a Bell System teletypewriter circuit

"Bell System furnishes us dependable communications at a price we can't equal"

—says Cyrus S. Gentry, President of the Wolverine Pipe Line Co.

Flexible, low-cost communications is what Wolverine Pipe Line Company is getting by renting private line teletypewriter service from the Bell System.

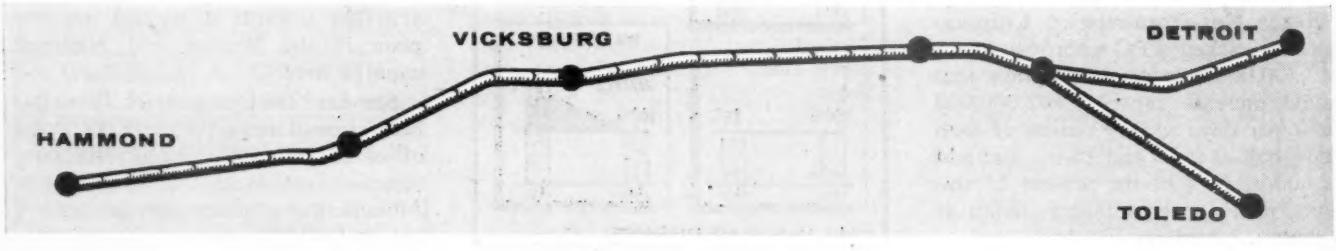
From Hammond, Indiana, products are started along the 295 miles of 16-inch pipe line to Detroit and Toledo. By using a Bell System teletypewriter circuit the operator starts or stops the big high-pressure pump at Vicksburg, 125 miles away.

Hundreds of miles east in New York, a dispatcher keeps round-the-clock watch over the Wolverine Pipe Line's seven stations. He gets reports and sends orders over Bell System teletypewriters.

"The expense of a privately owned system would be far in excess of a rented circuit," says a Wolverine official.

To find out how your communications efficiency could be improved, and costs lowered by using Bell System service, ask your Bell Telephone representative.

BELL TELEPHONE SYSTEM



PIPE LINE DEVELOPMENTS ★ ★ ★

Roundup of Current Planned and Proposed Construction

NAME OF COMPANY	MILES	PIPE SIZE	LOCATION
CRUDE LINES			
Ar-Mex Pipeline Co.	790	12-14	Guernsey, Wyoming to Coolidge, Arizona
Kaybee Pipe Line Company	46	10	Griffith, Indiana, to New Buffalo, Michigan
Michi, Inc.	222	10	Highland, Indiana, to Elsie and Alma, Michigan
NNCW Pipe Line Co.	127	8-10	Weston County to Casper, Wyoming
Orchard Pipe Line	45	8	Orchard to Merino, Colorado
Peace River Oil Pipe Line Co., Ltd.	200	12-16	Peace River area to Edson station on TransMountain near Edmonton, Alta
Powder River Pipe Line Company	436	10-16	Williston Basin to Laurel and Billings, Montana
Proven Oil & Refining Company	32	8	Connection with West Coast Pipe Line to Florence, Ariz.
Roosevelt Oil & Refining Corp.	22	4.6	St. Helen to Norwick, Michigan
Standard Pipe Line Co.	350	16	Glendive, Montana, to Guernsey, Wyoming
Standard Pipe Line Co.	330	16	Wink, Texas, to Albuquerque, New Mexico
Sinclair Pipe Line Company	31	12-16	Monee to Lemont, Illinois
Trans Mountain Oil Pipe Line Corp.	27	20	Laurel Junction to Mt. Vernon, Washington
Union Oil Company	65	12	Santa Clara Field to Wilmington Refinery
West Coast Pipe Line Company	960	20-22	Wink, Texas, to Norwalk, California
PRODUCTS LINES			
American Pipe Line Company	1910	8 to 26	Beaumont, Texas, to Newark, New Jersey, with laterals
California-Oregon Pipe Line System	103	6	Crescent City, California, to Medford, Oregon
Cherokee Pipe Line Company	8	8	Near Wichita, Kansas
H. W. Bass & Sons, Incorporated	152	4-6	Duval and Live Oak Counties, Texas, to Corpus Christi, Texas
Bell Oil and Gas Company	140	6-8	Ardmore to Cushing, Oklahoma
El Paso Natural Gas Co. (LPG Line)	119	3-6	Bloomington to Gallup, New Mexico
Great Lakes Pipe Line Co.	162	10	Eldorado, Kansas, to Kansas City, Missouri
Goliad Corporation (LPG Line)	117	4-6	Kittie Plant to Corpus Christi, Texas
Inland Corporation	22	6	Springfield to Dayton, Ohio
Inland Corporation	37.5	10	Toledo to Fostoria, Ohio
Inland Corporation	51	8	Lima to Fostoria, Ohio
International Pipe Line Inc.	132	8	Wrenshall to Minneapolis, Minnesota
Maico Pipeline, Inc.	91	6	Prewitt to Albuquerque, New Mexico
Mayflower Pipe Line Company	—	—	New Jersey refineries to New England points
Moore-Stoner Company	200	6	Glendive, Montana, to Minot, North Dakota
Phillips Petroleum Company	54	6	Goldsmith to Borger, Texas
Phillips Petroleum Company	52	10	Shell's Brookshire system to Sweeny, Texas
Shamrock Oil & Gas Corporation	55	6	McKee to Amarillo, Texas
Sunflower Pipe Line Company	265	3-6	Kearny, Grant and Haskell counties to Wichita, Kansas
Winnipeg & Central Gas Co. (LPG Line)	450	4 or 6	Tioga, N. D., to Winnipeg
GAS LINES			
Alberta Gas Trunkline	315	18-36	Gas Gathering System in Alberta fields
American-Louisiana Pipe Line Company	1120	22 & 30	Lowry, Louisiana, to Detroit, Michigan
Anadarko Basin Pipeline Co.	525	24	Wise County, Texas, to Memphis, Tennessee
Arkansas-Louisiana Gas Company	136	8 to 24	Loops on System
Central Hudson Gas and Electric Co.	48	12	TGT line to Kingston, N. Y.
City of Fayette, Alabama	20	5	Fayette, Alabama, to Southern Natural's system
Coast Counties Gas Electric Company	40	3-4-8	Coast and Valley Region, California
Colorado Interstate Gas Company	365	22	Green River, Wyoming to Denver, Colorado
Colorado Interstate Gas Company	110	6-8	Julesburg area to Denver, Colorado
Colorado-Western Pipe Line Co.	328	16-18	Ignacio field to Pueblo and Denver
Colorado-Western Pipe Line Co.	454	—	Cortez to Denver System
Colorado-Western Pipe Line Co.	250	—	Lateral lines
Cumberland and Allegheny Gas Co.	31	12	Garrett County, Maryland, to Keyser, West Virginia
El Paso Natural Gas Co.	370	—	Mountain Home, Idaho, to Reno, Nevada
Fort Worth Basin Gas Company	—	—	Brown and Comanche counties, Texas
Kansas Pipe Line Company	125	16-20	Barber County fields to Wichita, Kansas
Kansas-Nebraska Natural Gas Company	206	6-12	Additions to Nebraska system
Manufacturers Gas, Light & Heat	40	—	Allegheny, Washington, and Beaver counties, Pa.
Manufacturers Gas, Light & Heat	213	3 to 26	Various points on system in Pa., W. Va., and Ohio
Manufacturers Gas, Light & Heat	72	16-20	Doddridge, Wetzel and Marshall counteis, West Va.
Michigan Consolidated Gas Company	25	12	Sparata to Muskegon, Michigan
Michigan-Wisconsin Pipe Line Company	252	4-24	Loops and stations in Illinois
Mississippi River Fuel Corporation	190	10-18	Laterals in Woodlawn and Waskom gas fields, Texas
Morganfield Natural Gas	31	4-6	Through Sturgis, Providence, Clay, Diamond, Wheatcroft and Sullivan, Kentucky
Natural Gas Pipe Line Co. of America	280	24	Amarillo to Wise County, Texas
Natural Gas Producer, Inc.	100	12	Yenter pool to Denver, Colorado
Natural Gas Producer, Inc.	61	4-10	Northeast Colorado lines
New River Gas	50	—	Sumners to Monroe counties, West Virginia
North Dakota Natural Gas Company	475	6-12	Statewide system in North Dakota
Northern Indiana Fuel & Light	35	8	Edgerton to Alburn, Indiana
Northern Natural Gas Company	330	2-12	System in South Dakota
Northern Natural Gas Company	310	24	Lines in North Dakota
Northern Natural Gas Co.	400	24	Canadian border to Minneapolis-St. Paul
Northwest Utilities Ltd.	42	—	Bonnie Glen to Edmonton, Alberta, Canada
Pacific Northwest Pipeline Corp.	1486		Ignacio, Colorado to Bellingham, Washington
Pacific Northwest Pipeline Corp.	380		Laterals and spurs off main line to Pocatello, Idaho, to Yakima, Washington
Pine Tree Natural Gas Co.	204	—	Boston to Bangor, Maine
Rockland Light & Power Company	22	8	Orangetown to Tompkins Cover, New York
Shenandoah Gas Company	39	3-4-8	Middleton, Virginia, to Martinsburg, West Va.
South Georgia Natural Gas Company	368	2-12	Phoenix, Alabama, to Tallahassee, Florida
Tennessee Gas Transmission	243	24	Hebron, Pennsylvania to Greenwich, Connecticut
Texas Eastern Transmission Corp.	328	24	Beaumont to Kosciusko, Mississippi
Texas Gas Transmission Corporation	48	26	Loops on Memphis-Slaughter line
Transcontinental Gas Pipe Line Co.	421	30-36	Loops on Texas-New York main line
Trans-Canada Pipe Lines, Ltd.	2247	14-36	Alberta area to Toronto, Montreal
Union Gas Company of Canada	180	—	Dawn Storage field to Hamilton
United Natural Gas Company	50	12	Elk County to Jefferson County, Pennsylvania
Utah Natural Gas Company	40	16	Orem to Salt Lake City, Utah
Virginia Natural Gas Company	153	—	Buckingham to Richmond and Portsmouth, Va.
Warren Petroleum	54	4-30	Lea County, New Mexico
Westcoast Transmission Co., Ltd.	650	24	Peace River area, Alberta, to U. S.-Canadian border
Wyoming Gas Products Corp.	—	—	Gas gathering system in Weston County, Wyoming

Firing line, western Nebraska. In rolling country, welding equipment on trucks or track-mounted gave needed mobility, speeded up job.

P 615.05

Service Pipe Line's new 625-mile Wyoming-Missouri crude carrier . . .

Pipe Line in a Hurry

EXCLUSIVE

. . . Better than 10 miles built per day average

DEAN HALE*

Sideboom tractor, bogged down in eastern Kansas sinkhole, fights to free itself. Weather was generally good during construction.

HERE'S A RECIPE FOR SETTING RECORDS IN PIPE LINE CONSTRUCTION: **Take eight spreads of construction personnel, add an able group of company personnel, and mix well with large doses of determination, cooperation, and competitive spirit.**

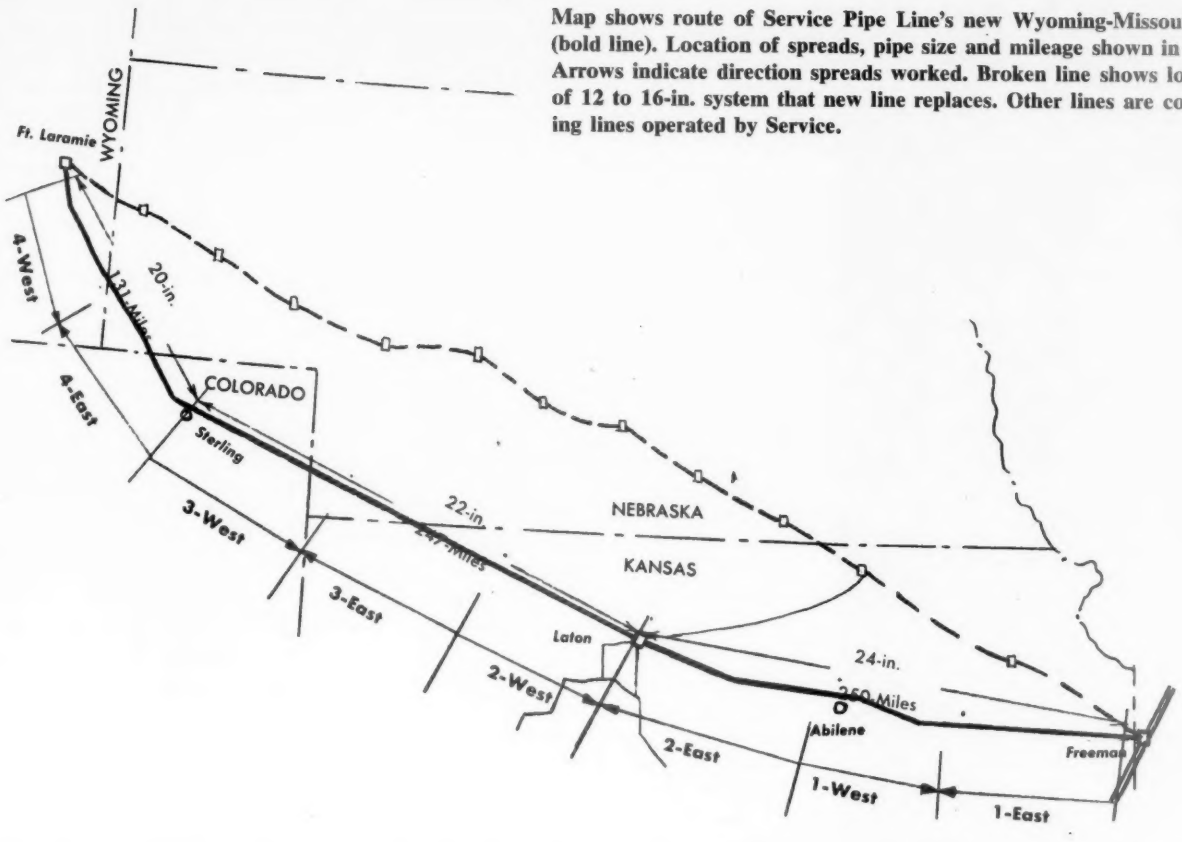
Service Pipe Line tried the mixture on the construction of its new 625-mile Wyoming to Missouri pipe line and ended up with another remarkable feat for the annals of the pipe line industry —a world's record for laying large-diameter pipe.

Climax of the undertaking came November 15 when the final weld was made, and lowering-in completed—just 61 days after the first right-of-way clearance was started.

Rapid completion of the new carrier meant much more than just a speed record in pipe-laying, however. The severe winters of the Rocky Mountains and western Kansas areas would have made pipe-laying slow and difficult. The fast pace also saved money for both the contractors and Service Pipe Line.

Many factors contributed to the rapid construction pace. Biggest of

*Editor, Oil . . . Gas . . . Products Pipelining.



Map shows route of Service Pipe Line's new Wyoming-Missouri line (bold line). Location of spreads, pipe size and mileage shown in color. Arrows indicate direction spreads worked. Broken line shows location of 12 to 16-in. system that new line replaces. Other lines are connecting lines operated by Service.

these was the wholehearted cooperation in every phase between the company and contractor organizations. An atmosphere of friendly rivalry among the personnel, prompted by a desire to finish "first" sprang up everywhere. Pipe stringers, suppliers of materials, landowners, citizens of communities along the route, and even the weather, joined forces to make the venture highly successful.

Planning Made Record Possible

In building the 625-miles of 20, 22, and 24-in. line in 61 days, for a record average of better than 10 miles per day, construction forces beat the time required to lay comparable sections of the war-speeded Big Inch and Little Inch and other post-war large-diameter line projects.

To do the job in a hurry, work was split into eight sections, with each of the two contractors furnishing four spreads. In sizing each section, factors such as terrain, soil conditions, possible weather conditions, etc., were taken into consideration. As construction progressed, the preliminary planning proved reasonably accurate despite the innumerable little delaying problems that arose. The weather generally was very cooperative, although some intermittent shutdowns were caused by high winds and rainy weather on various sections.

Early plans—considered at best "quite optimistic"—called for a target date of December 1 for completion of the line and operating date of December 15. The final weld was made on November 15. However, filling of the line started on completed sections on November 9 and complete fill was accomplished on December 21. Original plans had called for filling operations to start December 10.

New Line Has Big Potential

SERVICE'S NEW WYOMING-MISSOURI line consists of 130 miles of 20-in. pipe between Ft. Laramie and Sterling, 244 miles of 22-in. pipe between Sterling and Laton station, and 251 miles of 24-in. pipe between Laton and Freeman, Missouri, a junction point on Service's

96 Days—Decision to Final Weld

THE TIMETABLE:

August	12:	Decision made to build line; pipe orders placed.
August	18:	First option of right-of-way secured.
August	19:	Bid requests sent to contractors.
August	20:	First pipe shipped from mills.
August	24:	First survey party put in field.
August	25:	Construction contracts awarded.
August	26:	First pipe unloaded for job.
August	30:	First equipment unloaded by contractor.
September	16:	Right-of-way clearing started.
September	19:	First pipe lowered-in.
November	9:	First line-fill started.
November	15:	Final weld made.

SPREAD TIMETABLE:

Spread	Miles	Pipe Size	R/W Clearing Started	Welding Completed	Total Days
1-East	75	24-in.	Sept. 16	Nov. 15	61
1-West	75	24-in.	Sept. 16	Nov. 7	53
2-East	100	24-in.	Sept. 16	Oct. 30	45
2-West	82	22-in.	Sept. 17	Oct. 31	45
3-East	85	22-in.	Sept. 18	Nov. 14	58
3-West	80	22-in.	Sept. 18	Nov. 14	58
4-East	72	20-in.	Sept. 18	Nov. 5	49
4-West	59	20-in.	Sept. 18	Oct. 27	40

Wagon drills at work in eastern Kansas.

system from Texas and Oklahoma to Whiting, Indiana.

As have most postwar crude lines, Wyoming-Missouri was designed to give Service a more economical and more efficient operation. It replaces a 90,000 bbl per day, 12 and 16-in. system built in 1923 that follows the Platte River from Ft. Laramie through most of Nebraska and cuts across Northeast Kansas. The old system has 10 stations between Ft. Laramie and Freeman that are being shut down.

The new line will give Service increased capacity out of the Rocky Mountain area and it adds another important territory—the Denver-Julesburg basin in Colorado and western Nebraska—to the areas served by the company.

No Time Wasted

THE DECISION TO BUILD THE LINE came on August 12, and orders for pipe were placed on that day. The first right-of-way option was taken on August 18, six days after the decision to build the line was made. The first pipe was shipped from the mill August 20. Unloading sites had been selected by that time. The first survey crew was in the field August 24, and contracts for construction of the line were awarded August 25.

Service divided the project into two parts, with one contractor on each part. Company headquarters for the western section were at Sterling, Colorado, and the eastern section at Abilene, Kansas.

H. C. Jones, manager of the Service's Nebraska division, was in charge of construction on the western section. H. G. Mariner, manager of the company's Missouri division, was in charge of construction on the eastern section.

A friendly rivalry sprang up spontaneously between the company supervisors of the east and west sections, between the contractors on the two sections, and between the spreads within each section. Spreads were paired off against each other within the two sections and were given so many miles to cover. They started at opposite ends of their allotted sections and laid pipe toward a mid-point. If one spread reached the mid-point first, it continued on until it met the other spread.

This rivalry spurred the eight spreads into welding 108.6 miles of pipe during the week of October 14 through the 21st, an average of 15.5 miles per day. The record day in this period was 17.4 miles. During the same week one spread welded 3.64 miles (19,200 ft of 24-in. in one day and 23 miles for the entire week.

Daily progress reports on all jobs were consolidated in the field offices and phoned into Service's headquarters at Tulsa each morning where they were recorded and transcribed by stenographers. Progress was plotted on charts in Tulsa. In some instances where a spread had been delayed because of bad weather or other adverse conditions, men and equipment were sent to its assistance from another spread that had completed its work.

Designed for an initial capacity of 178,000 bbl per day into Freeman, the new line will be able to handle over 200,000 bbl daily with additional pump stations.

INITIALLY, THE FT. LARAMIE STATION will provide the "push" for 65,000 bbl of crude out of the Rocky Mountain area and another 30,000 bbl will be injected at Laton Station. Between Ft. Laramie and Laton, the elevation drop is 2174 ft, spread fairly evenly over most of the 375 miles between those two points. Out of Ft. Laramie, the line elevation rises over 1100 ft as it climbs to the Goshen Hole country, then drops 1400 to Sterling, and another 1900 ft into Laton. East of Laton, the drop is gradual into Freeman.

Pumping equipment at the present Ft. Laramie station is being utilized for the new line. At Laton, the present station will serve as an injection station for the 30,000 bbl of crude received from western Kansas lines of the company.

Provision has been made for a booster station at Sterling and provision has been made at Laton to convert that point to a full time booster station, when needed. At Laton, some manifold piping was installed during construction to tie-in the present station for its injection operation.

Working tankage at Laton, now

Pipe gang in Wyoming. Early snow had fallen at time of photo, near end of job on this section.

Clamshell cleans out cave-ins in sand hill country. Unit also used to put pad in trench at 30-ft intervals to receive pipe.

under construction, includes two 112,000 bbl tanks. Five others are planned: Two 132,000 bbl tanks at Ft. Laramie, one 132,000 bbl tank at Sterling, and two 176,000 bbl tanks at Freeman.

All are to be equipped with double-deck floating roofs. Each will have two 25-hp tank mixers, gaging equipment will be automatic, float-type with ground reading sight gage and remote transmission.

To protect the tank interiors, an improved coal tar product will be applied to the bottom, the lower two feet of the tank shells and rim plates of the floating roofs. Additionally, the tanks at Laton will also be protected by galvanic anodes installed inside the tanks.

Injection at Laton will be made at a time when the crude batch passing by the station is of the same grade as that being injected. A gravitometer is used to determine when to cut into the line for injecting.

The entire line was air tested for possible leaks or failures.

How It Was Built

NORMAL PROCEDURES WERE USED in building most of the line. For the ditch, a 40 by 46-in. cut was made for 20-in. pipe, 42 by 48 for 22-in. pipe, and 44 by 50 for 24-in. pipe. In the sand hill country, slopers were used on the trenching machines to keep cave-ins of the ditch wall to a minimum.

Pipe was given a normal cover of 20 to 24 in. In some areas, where farmers normally terrace or chisel their land, an extra 12 to 24-in. was added to the cover.

A 6-in. earth pad was put in the ditch by a small mobile clamshell unit at 30-ft intervals to receive the pipe.

Pipe protection included cleaning, priming, coating with an asphalt base enamel, and a 15-lb felt wrap. Lowering-in was done right behind the coating and wrapping operation. To cool the 20-in. pipe coating between Sterling, Colorado, and Albin, Wyoming, a machine developed by C-R-C was used, which deposits approximately 300 gal of water per minute on the surface of the pipe, and recirculates the water through an atmospheric type cooling tower. Remainder of line was cooled by means of a conventional spray ring with wetting agent in the water.

Most of the rock encountered on the line was in the flinthills east of Abilene, Kansas, where a dozer tractor, equipped with a hydraulic ripper, was used in both rocky and hard ground to make easier going for the ditching machines. After ripping a section, the dozer blade was lowered and right-of-way smoothed so that the ditching machine could travel without further preparation of the right-of-way.

In some locations, blasting was necessary as rock was extremely hard and ripper could not be used. On the west end, only about 1100 ft of rock was shot, most of it in stretches of about 100 ft.

During the latter stages of construction there was considerable cold weather. To get satisfactory welds, it was necessary to pre-heat the pipe ends of seamless pipe used on part of the job during this time.

This was done by using a ring-type burner, using butane, propane or oxy-acetylene as fuel, and heating the pipe ends from the inside just prior to depositing the root bead. All welds were completed before the root bead and hot pass bead had cooled.

Inspection by X-ray of welds was made on a minimum 10 per cent of the welds using the spot check method.

Gate valves were placed on the line at intervals of 30 to 50 miles, and at river crossings and other important points. All gates are through conduit type, 400 series.

Pipe used on the line included 16.19 miles of 20-in. weighing 65.71 lb per ft with a .312-in. wall thickness; 113.57 miles of .281-in. wall, 20-in. weighing 59.23 lb per ft; 10.56 miles of .344-in. wall, 22-in. weighing 79.51 lb per ft; 106.64 miles of .312-in. wall, 22-in. weighing 72.38 lb per ft; 127.14 miles of .281-in. wall, 22-in. weighing 65.24 per ft; 50.54 miles of .375-in. wall, 24-in. weighing 94.62 per ft, 30.19 miles of .344-in. wall, 24-in. weighing 86.85 per ft, and 170.82 miles of .312-in. wall, 24-in. weighing 79.06 lb per ft.

Approximately 100 miles of pipe—used between Laton station and Abilene—was double jointed at the mill and furnished in 60-ft lengths, a move which speeded the handling, stringing and welding operations.

Several of the highway, railroad, and ditch crossings posed some unusual problems. Near Sterling, one casing job ran 230 ft, and included going under a drainage ditch, U. S. highway 138, the Union Pacific railroad, and an irrigation ditch, all through caving sand. The annular space between casing and bore-hole was cemented with an oil-well cementing rig.

Near Kimball, Nebraska, at a point where the transcontinental telephone cable crossed under an irrigation ditch, an overhead pipe span was used. Only a short distance away, a long casing was made for a highway and railroad crossing.

In the irrigation country of northeastern Colorado, nearly a dozen overhead spans were needed in crossing the maze of irrigation ditches that traverse the area's farmland.

In eastern Kansas, a rock head was developed for the boring machine and used for several highway and railroad crossings where rock and hard earth was encountered. On the extreme eastern section, for some road crossings and railroad crossings, it was necessary to tunnel and blast.

Boom! Blast cuts ditch in eastern Kansas.

Seven of the eight major river crossings (which totaled 8500 ft) were laid in the conventional pull manner. All river pipe was coated with coal tar and glass wrap, encased in a concrete jacket for protection and to add additional weight. A different method, however, was used on the South Platte crossing near Sterling. A long crossing was needed here, as both the river and an adjacent irrigation ditch were crossed. After the trench was cut, jacketed pipe was laid out alongside the trench and skidded into the cut. Using sideboom tractors, the pipe was slid easily into the ditch.

Pipe was laid by O. R. Burden Construction Corporation, Tulsa, Oklahoma, and H. B. Zachry Company, San Antonio, Texas, who maintained four spreads each. J. L. Cox and Son, Raytown, Missouri; Parkhill Trucking Company, Tulsa, Oklahoma, and John Bunning Transfer Company, Rock Springs, Wyoming, strung the pipe. Aero Exploration Company, Tulsa, Oklahoma, shot the aerial maps. Weld X-ray was handled by Elder and McNulty, Tulsa, and Richardson X-ray Service, Alhambra, California.* * *

One of three pipe coating yards where nearly all of the 200 miles of pipe used on the Badger line was coated.

P 616.05

Many unusual right-of-way problems made

Badger Pipe Line Difficult Construction Project

New control system features operation of 267-mile products carrier built through highly congested urban and industrial sections to serve greater Chicago area

DEAN HALE*

BADGER PIPE LINE, which will begin initial operations this month, and full operation early this spring, has several unusual construction and operation features:

. . . *It will operate only as a carrier of products and will have no terminaling (tankage) facilities of its own.*

. . . *The system will be the first pipe line in the country to use a control system—adapted to pipe line operations—that has been successfully used by railroads for many years.*

. . . *Its right-of-way and construction problems were unusual in that a large portion of the line passes through highly congested urban territory.*

The 267-mile system, consisting of 200 miles of new construction, including 182 miles of 12-in. and 18 miles of 10-in., plus 67 miles of 8-in. purchased and incorporated into the system, is in the final stages of completion.

Constructed at a cost of approximately $11,000,000, Badger was organized as a stock company by four companies to build and operate a products pipe line to serve an area surrounding Chicago to the southwest and northward to Madison, Wisconsin. It will be the first products line built in Wisconsin.

Cities Service Pipe Line Company, designed, is constructing, and will operate the line for the joint owners, who are Cities Service Oil Company (Delaware), 32 per cent ownership; Sinclair Pipe Line Company, 34 per cent ownership; The Texas Company, 22 per cent ownership, and The Pure Oil Company, 12 per cent ownership.

Operating headquarters and dispatching offices of Badger Pipe Line will be located at Des Plaines, Illinois.

Plenty of Problems

Right-of-way and construction problems of the Badger line have created a large demand for aspirin among the pipeliners involved.

Much of the line's route passes through highly congested urban territory in the states of Indiana, Illinois, and Wisconsin. This is highly industrialized area, which is serviced by thousands of underground pipe lines and cables, many of which have never been mapped. There are also thousands of highways, streets, plain roads, railroads, and other major and minor thorofares.

For the best possible route, some 80 miles of the line is laid through street, highway, and railroad right-of-way. To do this, it was necessary to get permits from all the cities, counties, and states involved.

To prevent damage to the hidden, unknown, and unseen lines and cables buried over the Badger route, contractors took to using pipe locators. One contractor used the locators in three separate operations, beginning with detectors during right-of-way clearing and ending with a detector just ahead of the ditcher.

In addition to innumerable highway and railroad crossings, all of which were bored and cased, some up to 500 ft, the line had 10 river crossings ranging from a channel width of 51 ft up to 513 ft, plus approaches.The entire

*Editor, Oil . . . Gas . . . Products Pipelining.

EXCLUSIVE

right-of-way in Indiana was well-pointed, being in the low area adjacent to Lake Michigan, including nearly six miles of quicksand in a marshy area, where pipe was pushed through in sections.

River Crossings

Of the 11 river crossings made on the 200-mile line, eight were placed in the river bed and three were made on existing bridges. Of the latter, one 174-ft crossing over the Chicago District Drainage Canal and one over the Sag Canal were made on the highway 83 bridge, and the other, a 380-ft crossing of Little Calumet River, was made on the 130th Street Bridge.

For the underground river crossing, river pipe of 7/16-in. wall thickness was used, with a ½-in. thickness of somastic coating applied. No additional weight was added. Joints were coated with hot asphaltic enamel using patented field jointer envelopes.

Line pipe used in the new construction came in several grades and wall thicknesses. For the 12-in. line, pipe used included 15 miles of 5/16-in. X-42 grade, 3.5 miles of ¼-in. X-42, 42 miles of ¼-in. X-52, and 121.5 miles of ¼-in. X-46. All of the 10-in. pipe was ¼-in. X-42. All pipe was furnished in double random lengths.

In the Chicago area, inspection by X-ray was made on 100 per cent of the welds. In rural areas, a 10 per cent check was made.

All pipe on the system was coated with Somastic, and at the joint ends, field jointer envelopes were used, the annular space filled with enamel.

Highway and railroad crossings were cased with 16-in. pipe on the 12-in. line, and 14-in. casing was used on the 10-in. line.

Gate valves were placed on the main line at both sides of the river crossings, which were spaced at fairly regular intervals and eliminated the need generally for additional gates.

To complement the coating in combatting external corrosion, cathodic protection will be applied to the line. Leads are being installed at convenient points during construction and other equipment will be installed as work progresses. Insulating flanges are being installed at all points where regular flanges are used on the line.

Contractors include Morrison Construction Company, 28.8 miles of 12-in. and 11.4 miles of 10-in.; Contracting and Material Company, 95.8 miles of 12-in. and 6.7 miles of 10-in.; and Mid-States Construction Company, 57.4 miles of 12-in. H. C. Price Company contracted the application of Somastic coating to the 200 miles of 10 and 12-in. pipe.

Operations

Badger will begin operations with two stations, both of them "initial" stations, located at East Chicago and Lemont. Initial operating discharge pressure will be 450 psi, which will give a daily throughput of 27,500 bbl, and this can ultimately be raised to 900 psi and a daily throughput of 60,000 bbl. Additional stations can be added when needed.

Since Badger will operate only as a carrier of products, and have no terminaling or tankage facilities of its own, the only other facilities needed will be metering stations for receiving and delivering products.

The owner-users of the line, as well as any other shippers, will provide their own terminals and tankage. Distribution terminals will be located at Harlem Avenue, in southwest Chicago; Des Plaines; Rockford, and Madison.

Products will be received from Cities Service and Sinclair refineries at East Chicago, Pure's refinery at Lemont, and The Texas Company refinery at Lockport, and possibly others in the Chicago area.

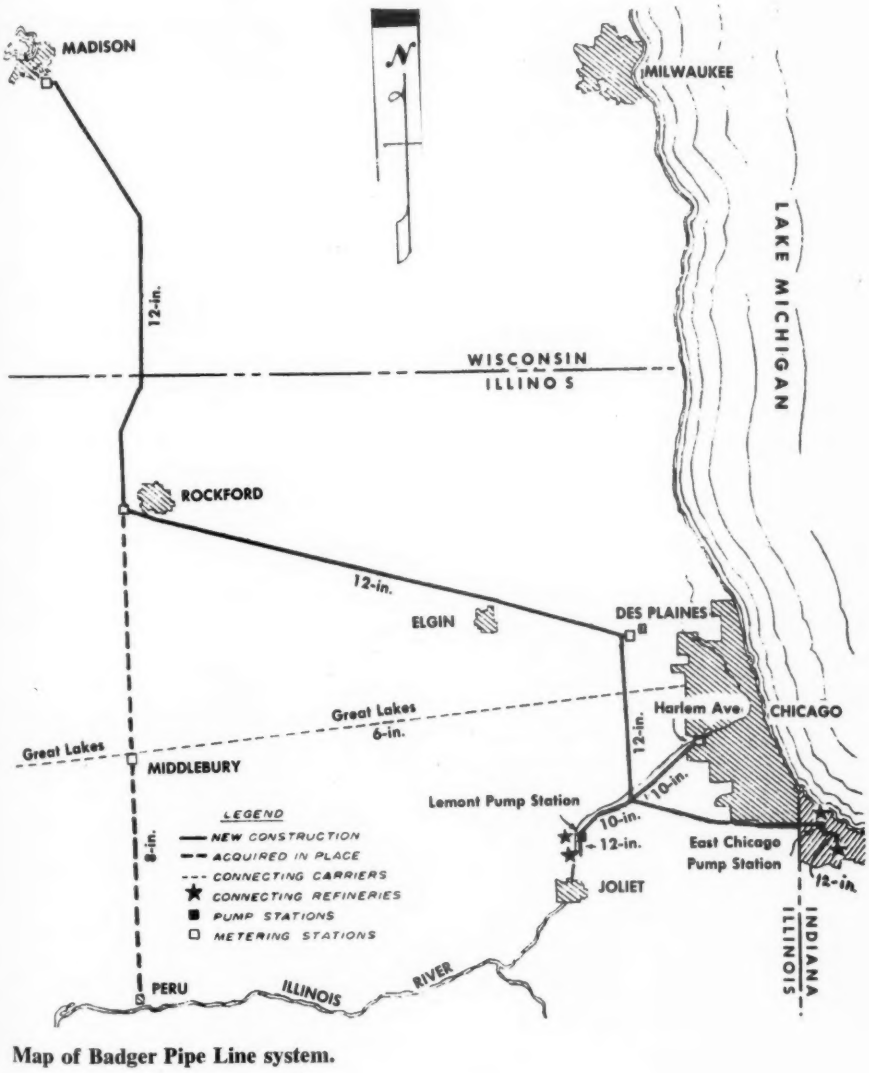
As part of the Badger system, a 67-mile, 8-in. line between Peru and Rockford was purchased from Sinclair Refining Company. Badger will be able to receive on this line products from Sinclair's Peru terminal on the Illinois Waterway, and also receive products from a connection at Middlebury with Great Lakes Pipe Line Company's intersecting 8-in. line.

Station Equipment

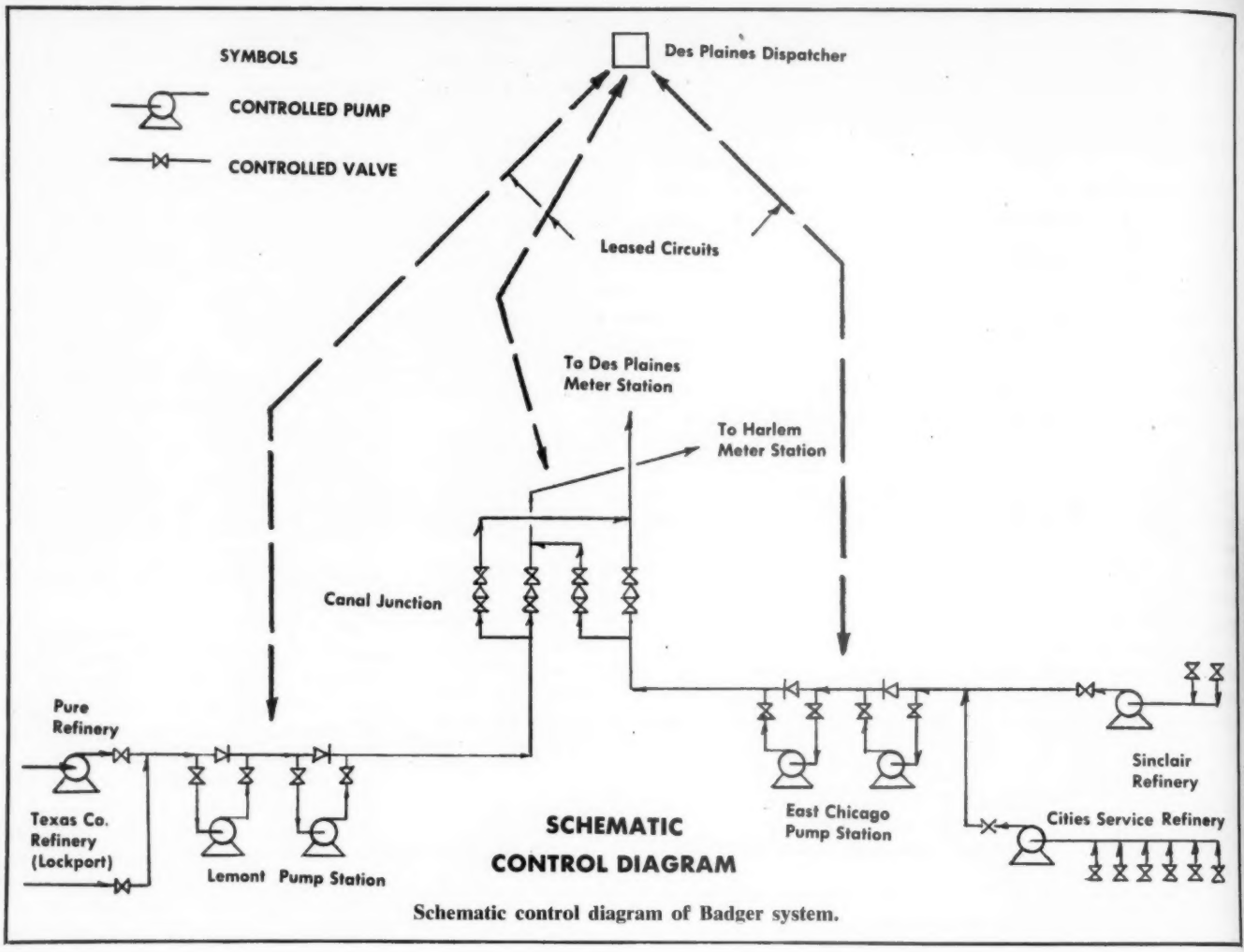
The Peru station, on the existing 67-mile, 8-in. line purchased from Sinclair Refining Company, is equipped with two 4 by 4-in., 4-stage centrifugal pumps driven by 250-hp, 2100 rpm diesel engines through 2:1 speed increasers.

Stations at East Chicago and Lemont will each contain two electric motor driven pumping units with provision for installing two additional units at each location, when needed. The motors are 300-hp, 3-phase, 60-cycle, 2300-v, 3600-rpm, class I, Group D, explosion-proof.

Power is purchased from local power



Map of Badger Pipe Line system.



Schematic control diagram of Badger system.

companies at each station site. Metal clad switchgear, located outdoors, is used as pump station substation equipment, and indoor unit control centers are provided for the metering stations.

The 6-in. centrifugal pumps used at the East Chicago and Lemont stations have a capacity of 72,500 bbl per day at 560-ft head. The pumps are equipped with mechanical seals. Bearings run in an oil bath and are cooled with the product being pumped.

Station buildings are masonry with a flat roof. The pump stations are 30 by 124 ft, with a 15- by 118-ft canopy. Meter stations are 30 by 69 ft, with a 15- by 69-ft canopy. The buildings are constructed of brick and steel, with a reinforced concrete foundation.

Ventilation of pump and engine rooms is provided by fixed louvres. Windows are galvanized steel ventilating sash. All fixtures are explosion proof. Process piping is generally overhead and drain piping is underground. Building wiring is overhead in rigid conduit and power wiring is underground, encased in concrete which has been colored red.

The stations have no auxiliary buildings and no auxiliary generating plant. Fire protection is provided by hand fire extinguishers and hydrants, which can be used in connection with hand foam appliers.

Manifold valves are 300 lb and 600 lb types. All lines are painted. A can-type vertical sump pump is provided, driven by a vertical, explosion-proof, electric motor. The incoming stream goes direct to pump suction.

Valves used range 2 to 12-in. in size and are of two types, plug and through conduit. Valves are both manual and motor operated.

Two slop tanks are provided at each meter station and are cone-roofed, 1500 bbl capacity.

Electronic products indicators will be used to determine the passage of interface. No sampling is required.

Station capacity varies from 13,000 to 80,000 bbl per day, depending on which station is being pumped, product being pumped, and point to which product is being pumped.

Inhibitors of the oil soluble type will be used to combat internal corrosion. These inhibitors will be injected into the product stream at the pump stations, using small proportioning pumps.

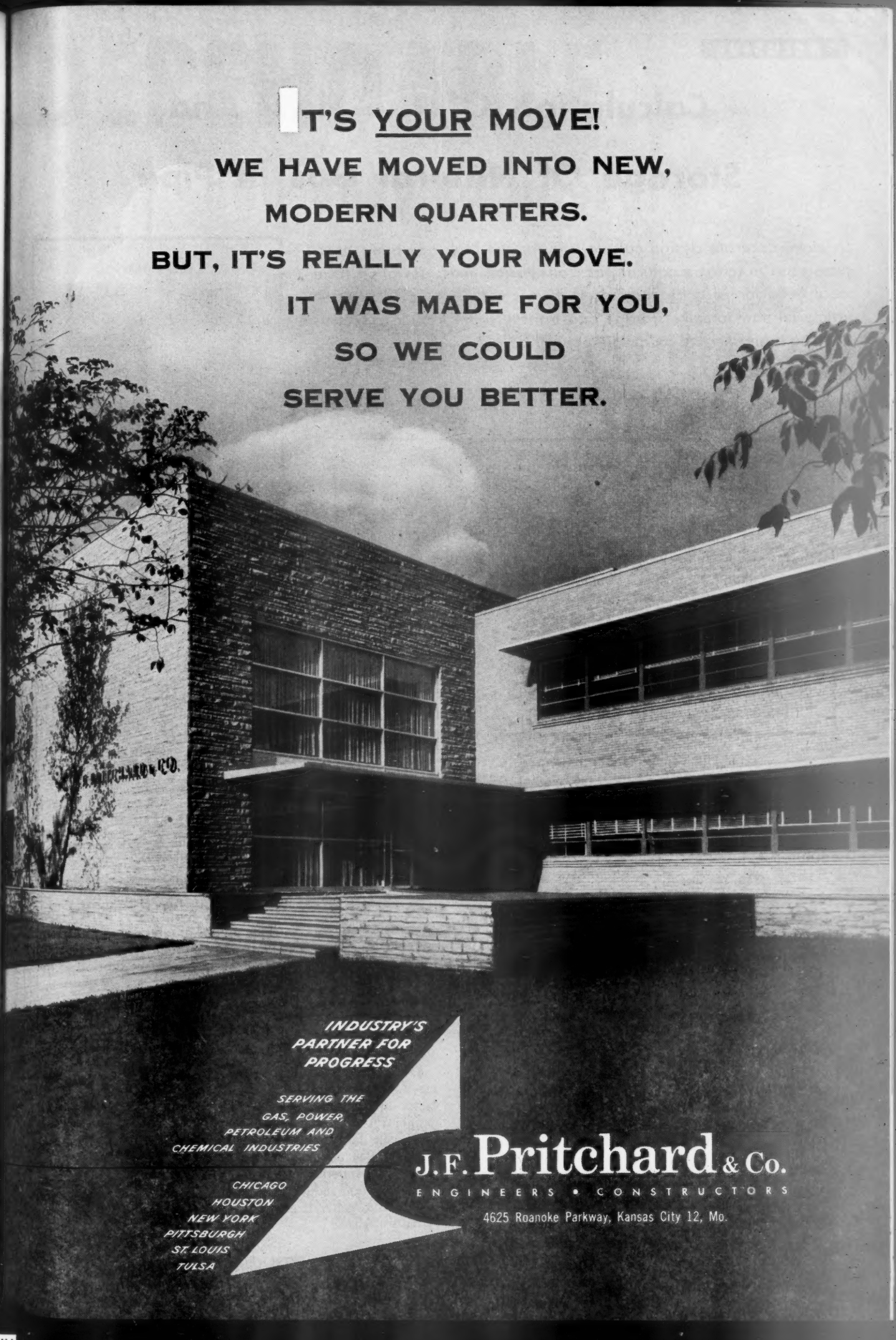
New Control System

Products dispatching on the Badger system will be handled by installation of a control system similar to that used by railroads for many years, and called "centralized traffic control."

Adapted to pipe line operations the control system uses coded impulses transmitted over leased telephone circuits for operation of refinery booster pumps, pump station valves and pumps (from either the individual pump station or dispatcher's office) and valves at pipe line junctions controlled directly from the dispatcher's office.

Briefly, the procedure is to operate a switch to open the motor-operated valve on the suction manifold of the refinery booster pump. When this valve reaches ⅓ open, the pump motor starts.

Ten seconds after the pump motor starts, the block valve at the Badger pump station starts to open. Badger pumping units are started by the opening motor-operated suction valve. When this valve becomes fully open and sufficient suction pressure is present, the pump motor starts. The discharge valve starts to open when the pump motor starts. The shutting down operation is the exact reverse of the starting procedure. *(An article discussing this control system and communication in detail will appear in the February Petroleum Engineer.)* * * *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EXCLUSIVE

Calculation Of The Flow And Storage Of Natural Gas In Pipe

To make accurate design calculations for the high operating pressures used in today's natural gas transmission lines, deviation from ideal behavior must be considered; here's the first of a three-part article on how to solve storage and transmission problems. Accompanying tables for the following text will be published in subsequent issues.

R. G. NISLE and FRED H. POETTMANN

Abstract

Tables of the integral functions

$$\left[\int_0^{P_r} \frac{P_r}{Z}\,dP_r\right]_{T_r} \quad \text{and} \quad \left[\int_0^{P_r} \frac{P_r^2}{Z^2}\,dP_r\right]_{T_r}$$

for natural gases were calculated using the IBM 602A calculating punch, and are presented herein for use in the Calculation of Volumetric Flow Rate and Storage Capacity, at standard conditions, of natural gas transmission lines. Equations for making such calculations are derived. The derivation of these equations rigorously accounts for the variation of the compressibility of natural gas with pressure and temperature. Examples demonstrating the use of the tables are given.

NOTE: In the formulas presented in the text and appendix which read P_r^2, this symbol may not appear to be clear to some readers. It should be construed as meaning the following: (P_r^2) . Typographical mechanics made it necessary to print it as given in the former case, where the square sign is spaced away from the quantity P.

The Authors

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Fred H. Poettmann is chief of Phillips production research section. He is a graduate of Case Institute of Technology and also has a MS and ScD from the University of Michigan. He joined the company in 1946 and has been engaged primarily in research on problems connected with reservoir engineering. He has taught graduate extension courses in chemical engineering through the Oklahoma A and M Extension Service in Bartlesville. Poettmann has worked as a chemist for the American Gas Association during summer vacations and worked a year as research chemist for the Lubrizol Corporation.

OPERATING pressures now in use in natural gas transmission lines require consideration of the deviation of the gas from ideal behavior when making calculations involving gas flow and storage capacity of the lines. For low pressure operations, equations such as the Weymouth equation for estimating both the flow and storage capacity of gas lines are satisfactory.[9] For high pressure operations deviation from ideal behavior must be considered, however, if accurate design calculations are to be made.

Of the specific flow equations available in the literature, that of Clinedinst[2] takes into consideration most rigorously the deviation of the natural gas from ideal behavior. The Clinedinst equation involves evaluation of the factor

$$\int_{P_{r2}}^{P_{r1}} \frac{P_r}{Z}\,dPr.$$

Neither Clinedinst nor other authors[2,4] who derived modifications of the Clinedinst equation have presented large scale working graphs or tables of these factors suitable for practical calculations. Similarly, in calculating the storage capacity of a transmission line, in addition to the above mentioned factor, values of

$$\int_{P_{r2}}^{P_{r1}} \frac{P_r^2}{Z^2}\,dPr \text{ are also used.}$$

During the course of some previous studies it was necessary to develop tables of some integrals of the compressibility factor of natural gas as functions of reduced pressure and temperature[8]. These tables were calculated using the IBM 602A calculating punch. Consequently there was available a deck of IBM punch cards containing Z, the compressibility factor, as a function of Pr, the pseudo reduced pressure, and Tr, the pseudo reduced temperature. The Z values were obtained from generalized curves of the compressibility factor of natural gases[1].

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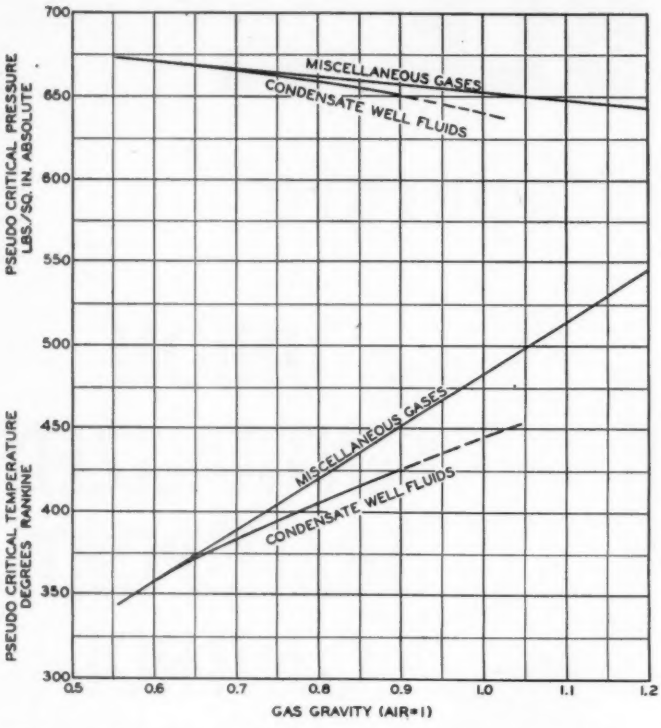


FIG. 1. Pseudo critical properties of condensate well fluids and miscellaneous natural gases.

In order to obtain tables of the integrals

$$\left[\int_0^{P_r} \frac{Pr}{Z}\,dPr\right]_{T_r} \quad \text{and} \quad \left[\int_0^{P_r} \frac{P_r^2}{Z^2}\,dPr\right]_{T_r}$$

it was only necessary, therefore to program the 602A to calculate these integrals as had been done previously for the other integrals, and run the data cards through the 602A. It is the purpose of this report to present the tables, so calculated, and to show how they can be used in solving transmission and storage problems.

Furthermore, this same deck of IBM punch cards may also be used in a similar manner to calculate any other desired function of the factors Z, Pr, and Tr. Such calculations would not necessarily be confined to the 602A calculating punch, but the more rapid 604 electronic calculating punch might be used. These cards might also be used, with the proper modification of techniques, in any problem involving Z, Pr, and Tr which it might be desired to solve on the IBM card-programmed calculator.

Gas Flow Equation

Of the available equations expressing the isothermal flow of gases in horizontal pipe, that of Clinedinst is the only one that takes into consideration rigorously the variation of the compressibility of the gas with pressure. It does make, however, the usual assumptions of other flow equations. These are:

1) The kinetic energy is negligible and can be taken as zero
2) Steady state isothermal flow
3) No differences in elevation

The thermodynamic derivation of the Clinedinst equation is given in Appendix 1.

In terms of flow rate the equation is written as follows:

$$Q = 1986.5\frac{Z_o\,T_o\,P_c}{P_o}\sqrt{\frac{D^5}{fLGT}\left[\int_0^{Pr_1}\frac{Pr}{Z}\,dPr - \int_0^{Pr_2}\frac{Pr}{Z}\,dPr\right]}$$

Where:

Q = Volumetric flow rate in MCFD measured at T_o and P_o
P_c = Pseudo critical pressure psia
P_o = Standard pressure in psia at which Q is measured
T_o = Standard temperature in degrees Rankine at which Q is measured
D = Inside diameter of pipe in feet
L = Length of pipe in feet
G = Gravity of gas relative to air
T = Flowing temperature in degrees Rankine
Z_o = Compressibility factor at T_o and P_o
P_r = Pseudo reduced pressure $= \dfrac{P}{P_o}$
f = Fanning friction factor, dimensionless

Values of the integral functions $\displaystyle\int_0^{P_r}\frac{Pr}{Z}\,dPr$ can be obtained from Table 1 of Appendix 3 as a function of the pseudo reduced pressure and pseudo reduced temperature. The pseudo critical pressure and temperature of a gas mixture is the molal average of the critical pressures and temperatures of the pure components comprising the gas mixture. If the gas composition is not available, Fig. 1 may be used to estimate the pseudo critical conditions from a knowledge of the gas gravity.

The gas gravity G can be calculated from the composition of the flow stream or experimentally measured. In the case of a gas-condensate where a small amount of liquid is entrained in the flow stream, the gravity of the entrained mixture can be obtained from Fig. 2.

Table 3 of Appendix 3 tabulates the internal diameter of various sized pipe as a function of pipe weight. In addition the internal diameter to the fifth power and cross-sectional area of the pipe are also tabulated.

There are many equations in the literature for determining the value of f. One of the best known is that of Moody, who, plots $f' = 4f$ as a function of the Reynolds Number with relative roughness as a parameter, Fig. 3[7]. Relative roughness is defined as the ratio of the absolute roughness of the pipe to pipe diameter. To use the relative roughness method it is necessary to establish a value for the absolute roughness of the pipe wall. Cullender and Binckley[3] have shown from an analysis of experimental flow data presented in U. S. Bureau of Mines Monograph 6 that an absolute roughness of 0.0006 in. is satisfactory for clean pipe[6].

The use of the Clinedinst Equation is perhaps best explained by means of a numerical example.

Example 1: A pipe line 100 miles long has an internal diameter of 13.375 in. The inlet pressure is 1300 psia and the pressure at the end of the line is 300 psia. The temperature of the flowing gas is 40 F and its composition is as follows:

Methane: 75 mole per cent
Ethane: 21 mole per cent
Propane: 4 mole per cent

Calculate the volumetric flow rate at 14.65 psia and 60 F.

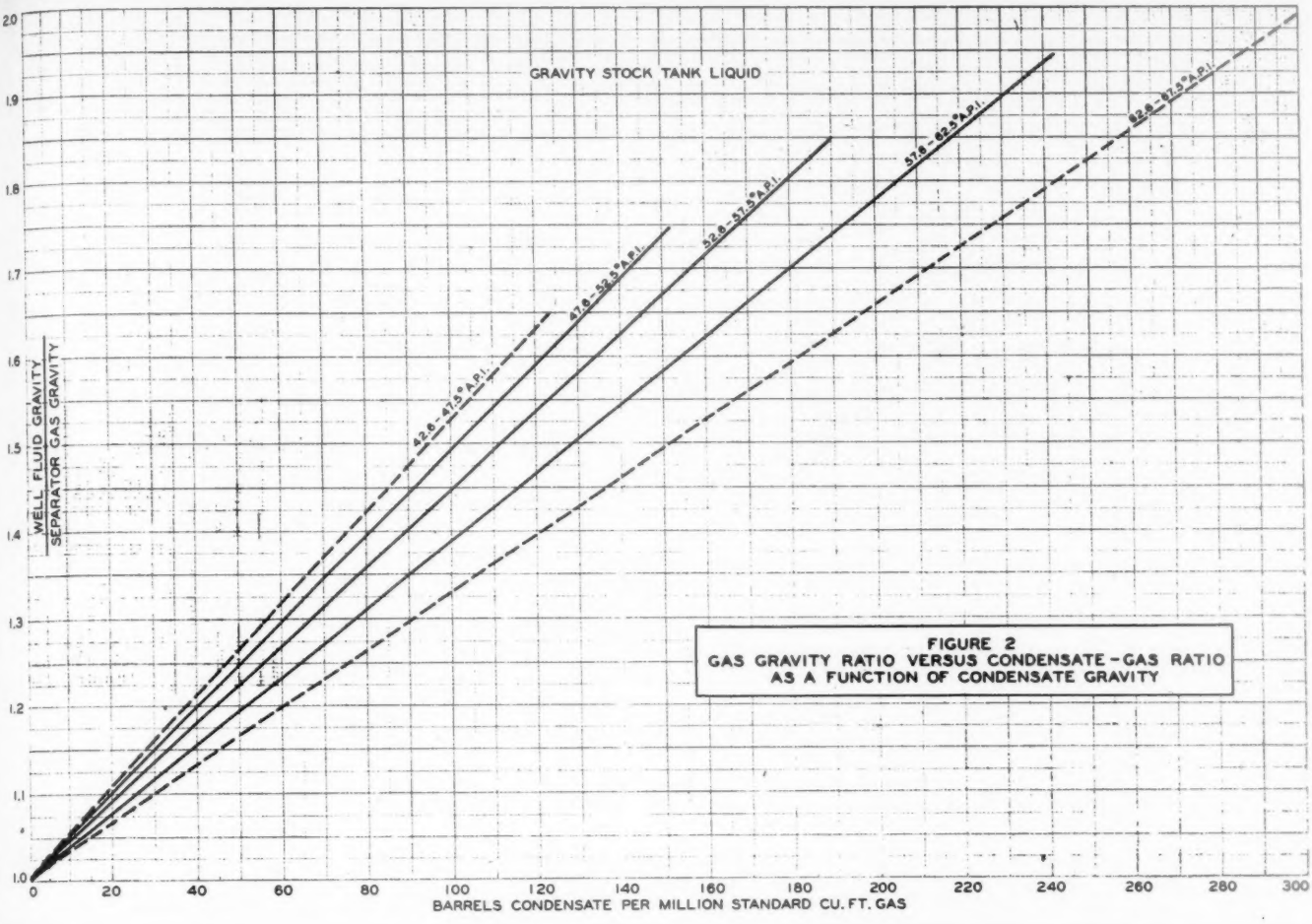

GRAVITY STOCK TANK LIQUID
WELL FLUID GRAVITY / SEPARATOR GAS GRAVITY
42.6 - 47.5° A.P.I.
47.6 - 52.5° A.P.I.
52.6 - 57.5° A.P.I.
57.6 - 62.5° A.P.I.
62.6 - 67.5° A.P.I.
BARRELS CONDENSATE PER MILLION STANDARD CU. FT. GAS

FIGURE 2
GAS GRAVITY RATIO VERSUS CONDENSATE-GAS RATIO AS A FUNCTION OF CONDENSATE GRAVITY

Solution:

Gas composition

Methane:	75	mole per cent
Ethane:	21	mole per cent
Propane:	4	mole per cent
	100	mole per cent

Standard conditions: 60 F, 14.65 psia

Pipe line conditions: 40 F,

Dimensions: L = 100 miles = 5.28×10^5 ft
D = 13.375 in. (inside diameter) = 1.1145 ft.

Inlet pressure held at 1300 psia (P_1)

Discharge pressure 300 psia (P_2)

Molecular weights and critical pressures and temperatures of the gas components are as follows:

Component	Molecular wt.	Critical Pressure	Critical Temperature
Methane	16	673 psia	344 R
Ethane	30	712	549
Propane	44	617	666

From this data the pseudo critical pressure and temperature are calculated. They are:

$$P_c = 678.95 \text{ psia}$$

$$T_c = 399.93 \text{ R}$$

The pseudo reduced pressures are

$$Pr_1 = \frac{1300}{678.95} = 1.91$$

$$Pr_2 = \frac{300}{678.95} = .44$$

The pseudo reduced temperature at flow conditions is

$$Tr = \frac{460 + 40}{399.95} = 1.25$$

The integral terms as read from Table 1, Appendix 3 are:

$$\left[\int_0^{1.91} \frac{Pr}{Z} dPr\right]_{Tr = 1.25} = 2.43; \qquad \left[\int_0^{.44} \frac{Pr}{Z} dPr\right]_{Tr = 1.25} = 0.10;$$

Friction factor = .0027 (¼ of Fig. 3)

Gas gravity = .69

$$Q \text{ (MSCF/D)} = \frac{1986.5 \times 1.000 \times 520 \times 678.95}{14.65} \sqrt{[2.43 - 0.10] \frac{(1.1145)^5}{.0027 \times 5.28 \times 10^5 \times .69 \times 500}}$$

Q = 136,640 MCFD at 14.65 psia and 60 F.

Gas Storage Capacity

An important secondary function of natural gas pipe lines is that of storage. Weymouth defined the storage capacity of a natural gas pipe line as the difference between the gas content of the pipe line during packed and unpacked conditions[9]. By packed condition is meant that case where the withdrawal from the line is a minimum and as a result the discharge pressure is a maximum for the condition where the supply of gas to the line is a constant. Similarly an unpacked condi-

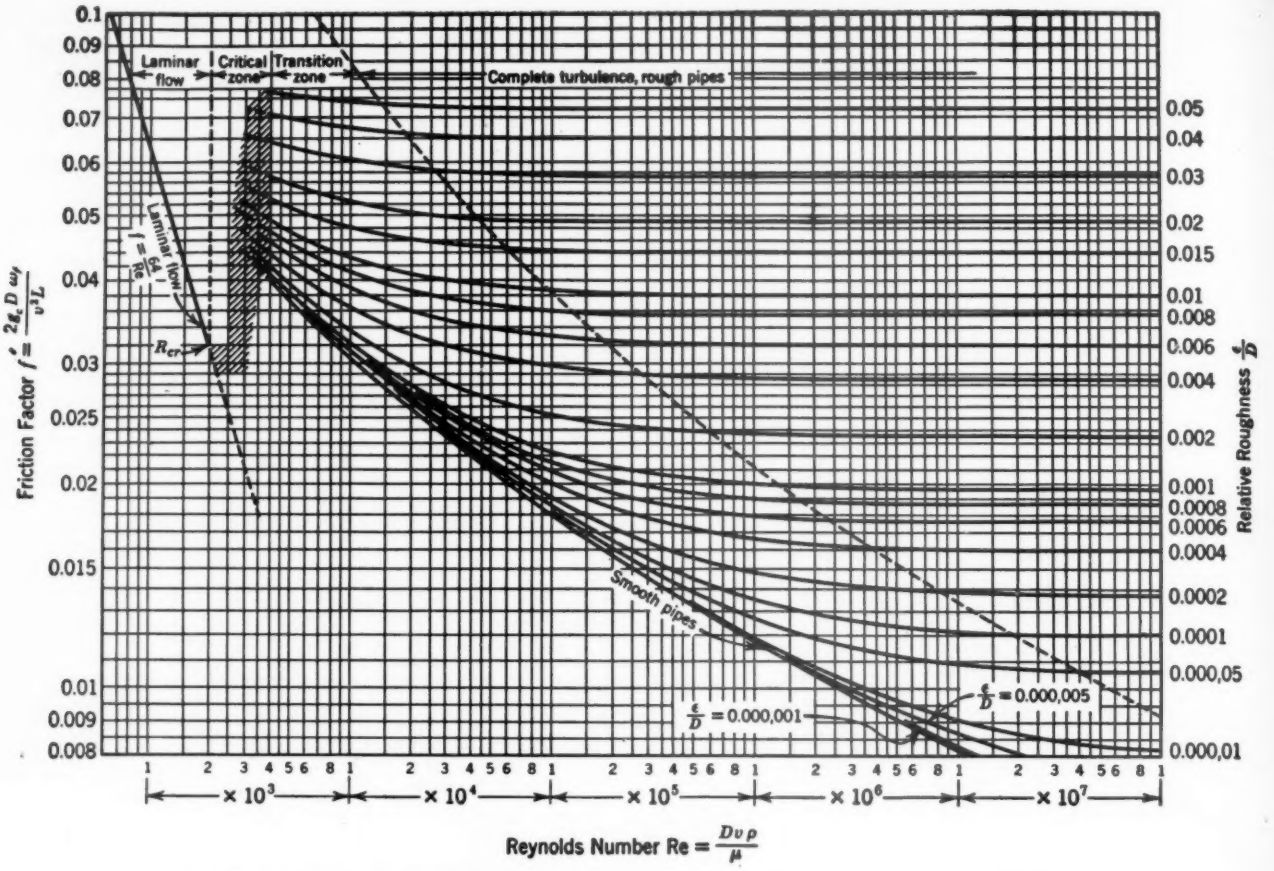


FIG. 3. Friction factor as a function of Reynolds number with relative roughness as a parameter.

tion exists when withdrawals are a maximum and the pressure is a minimum, for a constant supply of gas to the line.

Using this definition of storage capacity, Joffe[5] derived an expression for calculating the storage capacity of a natural gas pipe line which takes into consideration rigorously the variation of compressibility of the gas with pressure. It also, however, makes the same assumption used in deriving the Clinedinst equation. The correction factor employed by Joffe is the ratio of the value of the integral for a real gas to that of the ideal gas value. Similarly the "correction factor" charts presented by Joffe are too small to be suitable for practical calculations.

The authors prefer to deal with the integral functions directly and not as correction factors compared with those for ideal gas behavior. The derivation of an expression for computing the contents of a natural gas pipe line under conditions of steady state isothermal flow is given in Appendix 2.

The equation is written as follows:

$$V_o = \frac{AL\ Z_o\ T_o\ P_c}{P_o\ T}\left[\frac{\int_0^{Pr_1}\frac{P_r^2}{Z^2}\,dPr - \int_0^{Pr_2}\frac{P_r^2}{Z^2}\,dPr}{\int_0^{Pr_1}\frac{Pr}{Z}\,dPr - \int_0^{Pr_2}\frac{Pr}{Z}\,dPr}\right]$$

Where:

V_o = Volume of gas in pipe line measured at T_o and P_o, cubic feet
A = Cross sectional area of pipe in square feet
L = Length of pipe in feet
T = Temperature °R
P_o = Standard pressure psia
T_o = Standard temperature °R
Z_o = Compressibility factor at T_o and P_o
P_c = Pseudo critical pressure of gas, psia

Values of the integrals $\int_0^{P_r}\frac{P_r}{Z}\,dP_r$ and $\int_0^{P_r}\frac{P_r^2}{Z^2}\,dPr$ can be obtained from Tables 1 and 2 respectively of Appendix 3 as functions of the pseudo reduced pressure and temperature. The increments of temperature and pressure in the tables have been taken close enough so that linear interpolation can be used.

The use of the equation in calculating the storage capacity of a gas pipe line is illustrated by the following example:

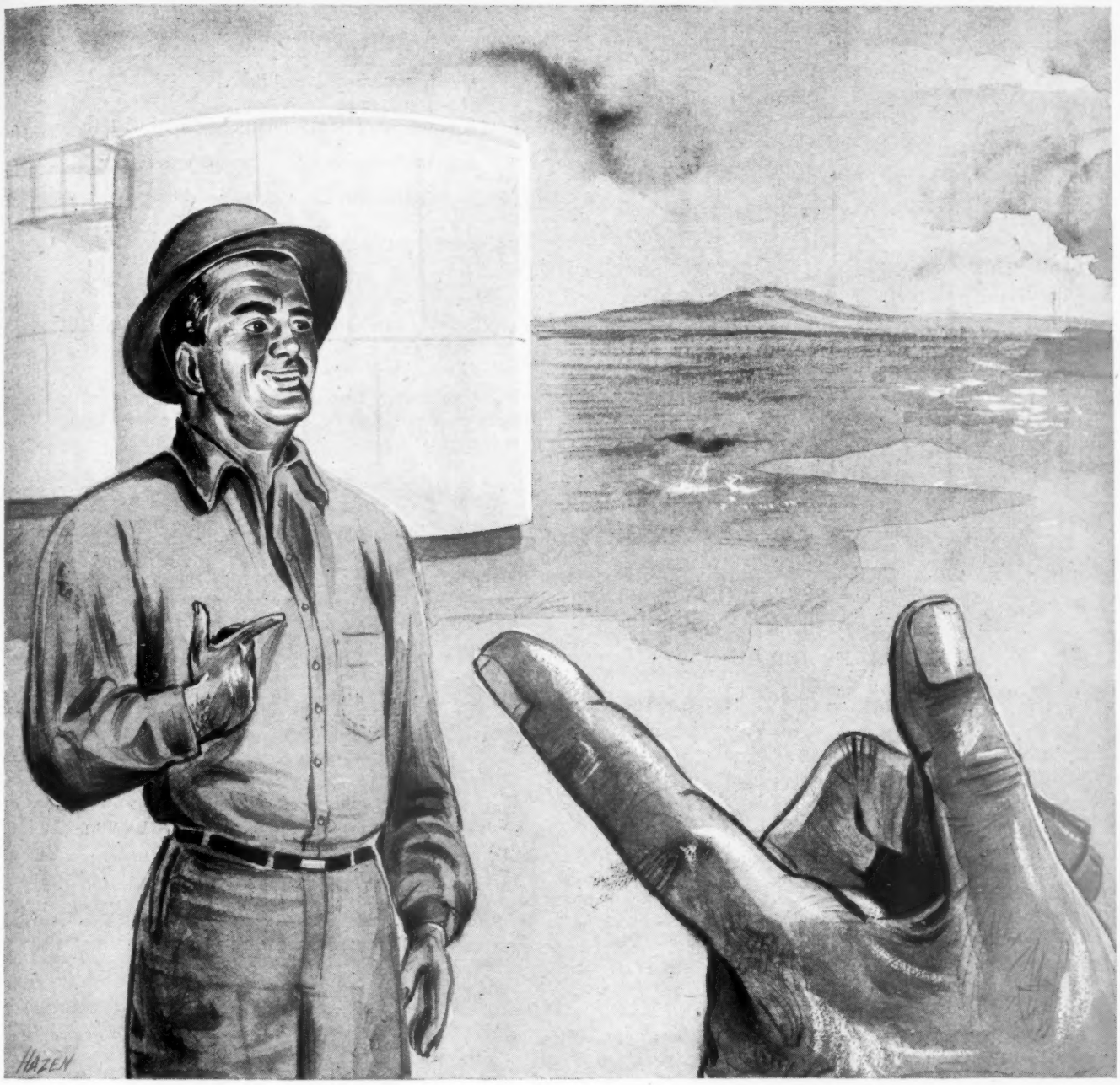
Example 2 — Using the description of the pipe line given in example 1, calculate the storage capacity of this line in cubic feet of gas measured at 60 F and 14.65 psia when for unpacked conditions the pressure at the end of the line is 300 psia and for packed conditions is 1000 psia.

Solution:

In this example the conditions are the same as in the flow rate example except for the following:

Packed condition

P_1 = 1300 psia, Pr_1 = 1.91
P_2 = 1000 psia, Pr_2 = 1.47



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Unpacked condition

$P_1 = 1300$ psia, $Pr_1 = 1.91$

$P_2 = 300$ psia, $Pr_2 = 0.44$

The values of the integrals as obtained from Table 1 and 2 of Appendix 3 are

$$\left[\int_0^{1.91} \frac{Pr}{Z}\,dPr\right]_{T_r = 1.25} = 2.43; \quad \left[\int_0^{1.47} \frac{Pr}{Z}\,dPr\right]_{T_r = 1.25} = 1.30;$$

$$\left[\int_0^{0.44} \frac{Pr}{Z}\,dPr\right]_{Tr = 1.25} = 0.10; \quad \left[\int_0^{1.91} \frac{P_r^2}{Z^2}\,dPr\right]_{T_r = 1.25} = 4.52;$$

$$\left[\int_0^{1.47} \frac{P_r^2}{Z^2}\,dPr\right]_{T_r = 1.25} = 1.71; \quad \left[\int_0^{0.44} \frac{P_r^2}{Z^2}\,dPr\right] = 0.032 = 0.32;$$

$$V \text{ packed} = \frac{\frac{\pi (1.1145)^2}{4} \times 5.28 \times 10^5 \times 1 \times 520 \times 678.95}{14.65 \times 500} \times \left[\frac{4.52 - 1.71}{2.43 - 1.30}\right]$$

$$= 2.4826 \times 10^7 \left[\frac{2.81}{1.13}\right] = 6.1736 \times 10^7$$

$$V \text{ unpacked} = 2.4826 \times 10^7 \left[\frac{4.52 - 0.03}{2.43 - 0.10}\right]$$

$$= 2.4826 \times 10^7 \left[\frac{4.49}{2.33}\right] = 4.7841 \times 10^7$$

$$\text{Storage capacity} = (6.1736 - 4.7841) \times 10^7$$

$$= 1.3895 \times 10^7 = \underline{13{,}895{,}000}$$

Storage capacity = 13,895,000 cu ft of storage capacity measured at 60 F and 14.65 psia.

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Appendix 1

The basis for the derivation of any fluid flow equation is an energy balance on the flowing fluid between two points in the system under consideration.

This basic energy balance may be written:

$$\int_1^2 VdP + \triangle h + \triangle\left(\frac{v^2}{2g_c}\right) + W_f + W_s = O \quad . \quad . \quad . \quad (1)$$

For the flow of natural gas in a pipe, this general equation may be considerably simplified by means of certain assumptions.

(1) Steady state isothermal flow.
(2) Horizontal pipe ($\triangle h = 0$)
(3) Kinetic energy term small compared with the remaining terms, hence $\triangle \frac{v^2}{2g_c}$ is taken to be zero.
(4) No external work is done on or by the flowing gas ($W_s = 0$)

Equation 1 therefore, reduces to:

$$\int_1^2 VdP + W_f = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1a)$$

W_f is an energy loss due to the irreversibilities of a real flowing fluid and can be expressed by the well-known Fanning equation:

$$W_f = \int_{L_1}^{L_2} \frac{4fv^2}{2g_c D}\,dL$$

Equation (1a) becomes:

$$\int_{P_1}^{P_2} Vdp + \int_{L_1}^{L_2} \frac{4fv^2}{2g_c D}\,dL = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1b)$$

If V = specific volume in cu ft/lb and m = number of pounds flowing per second, then, mv = total volume flowing per second and:

$$v = \frac{mV}{\pi/4D^2} \text{ in feet per second} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Substituting (2) in (1b) we have

$$\int_{P_1}^{P_2} VdP + \int_{L_1}^{L_2} \frac{4f\,m^2\,V^2}{2g_c D^5\,(\pi/4)^2}\,dL = 0$$

Since V is a function of P only, and does not depend on L, the V^2 may be taken out of the second integral and we may write,

$$\int_{P_1}^{P_2} \frac{dP}{V} + \int_{L_1}^{L_2} \frac{2f\,m^2}{g_c(\pi/4)^2 D^5}\,dL = 0 \quad . \quad . \quad . \quad . \quad . \quad (3)$$

But $V = \frac{ZRT}{29\,GP}$

Therefore,

$$\frac{29\,G}{RT}\int_{P_1}^{P_2} \frac{P}{Z}\,dP + \frac{2fm^2\,L}{(\pi/4)^2 g_c D^5} = 0$$

$$\int_{P_2}^{P_1} \frac{P}{Z}\,dP = \frac{2fm^2 L}{(\pi/4)^2 g_c D^5} \quad \frac{RT}{29G}$$

$$m^2 = \left(\frac{\pi}{4}\right)^2 \frac{g_c D^5}{2fL} \quad \frac{29G}{RT} \int_{P_2}^{P_1} \frac{P}{Z}\,dP$$

$$Q = \frac{mZ_oRT_o\,(86400)}{29G\,P_o\,(1000)}$$

$$m = Q\,\frac{29G\,P_o\,(1000)}{Z_oR\,T_o\,(86400)}$$

$$Q^2\left(\frac{29G\,P_o\,(1000)}{Z_oR\,T_o\,(86400)}\right)^2 =$$

$$\left(\frac{\pi}{4}\right)^2 \frac{g_c D^5\,29\,GP_c^2}{2fLRT} \int_{Pr_2}^{Pr_1} \frac{Pr}{Z}\,dPr \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$Q = \left[\frac{R^{1/2}\,(86400)\,\pi\,g_c^{1/2}}{29^{1/2} \times 4 \times 2^{1/2}\,(1000)}\right] \frac{Z_o\,T_o\,P_c}{P_o} \times \sqrt{\frac{D^5}{fLGT}\left[\int_O^{Pr_1} \frac{Pr}{Z}\,dPr - \int_O^{Pr_2} \frac{Pr}{Z}\,dPr\right]}$$

$$Q = 1986.5\,\frac{Z_o\,T_o\,P_c}{P_o} \sqrt{\frac{D^5}{fLGT}\left[\int_O^{Pr_1} \frac{Pr}{Z}\,dPr - \int_O^{Pr_2} \frac{Pr}{Z}\,dPr\right]}$$

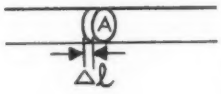
Appendix 2

The equation for the storage capacity of the horizontal pipe line may be derived as follows:

Volume of elementary section of pipe = Adl

V = specific volume,

Then,



$dm = \frac{Adl}{V}$ = mass contained in elementary volume.

$V = \frac{ZRT}{PM}$, M = molecular weight of gas

$\bar{m}$ = mass flow rate in lb/sec.

We have, therefore,

$$dm = \frac{PMA}{ZRT}\,dl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Equation 3, appendix 1 may be written

$$-\frac{dp}{V} = \frac{2f\bar{m}^2}{g_cA^2D}\,dl \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$dl = -\frac{g_c\,A^2D}{2f\bar{m}^2} \quad \frac{MP}{ZRT}\,dP \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2a)$$

$$dm = -\frac{PMA}{ZRT} \quad \frac{g_cA^2D}{2f\bar{m}^2} \quad \frac{MP}{ZRT}\,dP$$

$$dm = -P_c^3\,\frac{M^2A^3g_c\,D}{2fm^2R^2T^2} \quad \frac{P_r^2}{Z^2}\,dPr \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Integration of (3) gives the total mass of gas in the pipe line when the pressures are Pr_1 and Pr_2. M is a flowing mass.

$$\int_O^{\mathcal{M}} dm = \mathcal{M} = P_c^3\,\frac{M^2\,A^3\,D\,g_c}{2fm^2\,R^2T^2} \times \int_O^{Pr_1} \frac{P_r^2}{Z^2}\,dPr - \int_O^{Pr_2} \frac{P^2}{Z^2}\,dPr$$

(2a) above may be written

$$P_c^2 \int_{Pr_1}^{Pr_2} \frac{Pr}{Z}\,dPr = \frac{2f\bar{m}^2\,RTL}{g_cA^2DM}$$

$$\int_O^{Pr_1} \frac{Pr}{Z}\,dPr - \int_O^{Pr_2} \frac{Pr}{Z}\,dPr = \frac{2f\bar{m}^2RTL}{A^2g_cDM} \quad \frac{1}{P_c^2}$$

$$\mathcal{M} = \frac{\dfrac{P_cMAL}{RT}}{\dfrac{2f\bar{m}^2RTL}{A^2g_cDMP_c^2}}\left[\int_O^{Pr_1} \frac{P_r^2}{Z^2}dPr - \int_O^{Pr_2} \frac{P_r^2}{Z^2}dPr\right]$$

$$\mathcal{M} = P_c\,\frac{MAL}{RT}\left[\frac{\displaystyle\int_O^{Pr_1} \frac{P_r^2}{Z^2}dPr - \int_O^{Pr_2} \frac{P_r^2}{Z^2}dPr}{\displaystyle\int_O^{Pr_1} \frac{Pr}{Z}dPr - \int_O^{Pr_2} \frac{Pr}{Z}dPr}\right] \quad . \quad (4)$$

$$P_oV_o = \frac{\mathcal{M}}{M}\,Z_oRT_o$$

$$\frac{V_oP_o}{Z_oRT_o} = \frac{P_cAL}{RT}\left[\frac{\displaystyle\int_O^{Pr_1} \frac{P_r^2}{Z^2}dPr - \int_O^{Pr_2} \frac{P_r^2}{Z^2}dPr}{\displaystyle\int_O^{Pr_1} \frac{Pr}{Z}dPr - \int_O^{Pr_2} \frac{Pr}{Z}dPr}\right]$$

$$V_o = \frac{AL\,Z_oT_oP_c}{P_oT}\left[\frac{\displaystyle\int_O^{Pr_1} \frac{P_r^2}{Z^2}dPr - \int_O^{Pr_2} \frac{P_r^2}{Z^2}dPr}{\displaystyle\int_O^{Pr_1} \frac{Pr}{Z}dPr - \int_O^{Pr_2} \frac{Pr}{Z}dPr}\right]$$

To find storage capacity, calculate V_o' at (Pr_1, Pr'_2) for maximum flow rate, and V_o'' at (Pr_1, Pr''_2) for minimum flow rate. Then storage capacity is $V_o'' - V_o'$.

Calculations of the Flow and Storage of Natural Gas in Pipe

APPENDIX 3

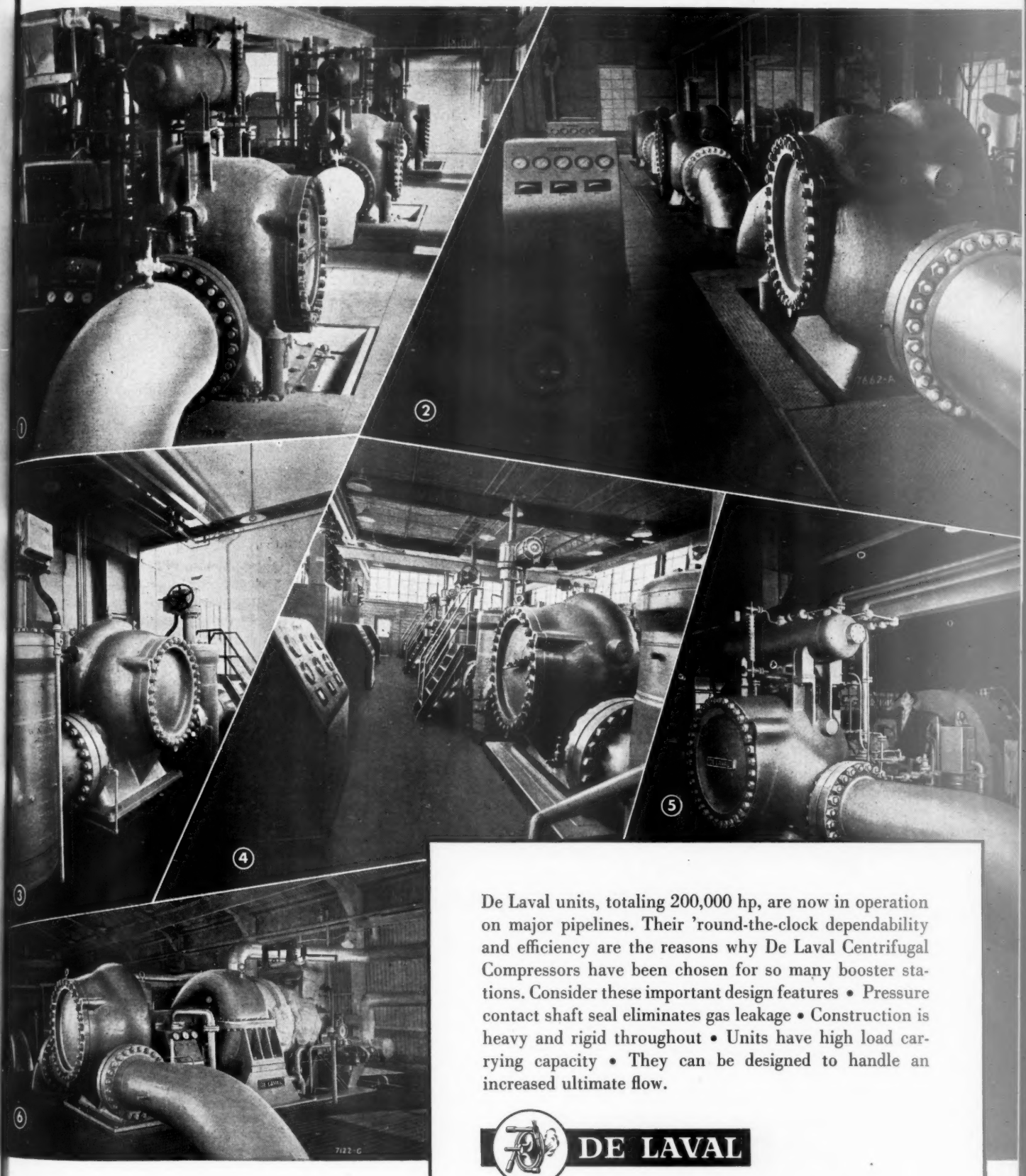
Table 3. Steel pipe dimensions.

Diameter in inches x 8.333×10^{-2} = Diameter in feet.
Area in square inches x 6.944×10^{-3} = Area in square feet.
Fifth power of inside diameter in inches^5 x 4.019×10^{-6} = Fifth power of inside diameter in feet^5

Weight of pipe lb/ft	Inside dia. inches	Fifth power of ID (thousands inches^5)	Flow area sq in.
3 in. nominal size (outside diameter, D = 3.500″)			
4.33	3.260	368.2	8.35
4.51	3.250	362.6	8.30
5.30	3.204	337.6	8.06
6.65	3.124	297.6	7.66
7.58	3.068	271.8	7.39
8.39	3.018	250	7.15
8.81	2.992	240	7.03
9.91	2.922	213	6.71
10.25	2.900	205	6.60
10.64	2.875	196	6.49
13.43	2.687	140	5.67
14.33	2.624	124	5.41
18.58	2.300	64	4.15
3½ in. nominal size (outside diameter D = 4.000″)			
4.97	3.760	752	11.10
5.29	3.744	736	11.01
5.53	3.732	724	10.94
6.09	3.704	697	10.78
7.65	3.624	625	10.31
9.11	3.548	562	9.89
11.16	3.438	480	9.28
12.51	3.364	431	8.89
13.43	3.312	399	8.62
17.69	3.062	269	7.36
22.85	3.728	151	5.84
4 in. nominal size (outside diameter = 4.500″)			
5.61	4.260	1403	14.25
5.98	4.244	1377	14.15
6.25	4.232	1358	14.07
6.61	4.216	1332	13.96
7.64	4.170	1261	13.66
8.66	4.124	1193	13.36
9.40	4.090	1144	13.14
10.79	4.026	1058	12.73
11.35	4.000	1024	12.57
12.24	3.958	971	12.30
12.72	3.938	947	12.18
13.46	3.900	902	11.95
13.96	3.876	875	11.80
14.99	3.826	820	11.50
16.52	3.750	742	11.04
19.00	3.624	625	10.31
21.36	3.500	525	9.62
22.51	3.438	480	9.28
27.54	3.152	311	7.80
5 in. nominal size (outside diameter = 5.563″)			
7.77	5.295	4162	22.02
14.62	5.047	3275	20.01
19.59	4.859	2708	18.54
20.78	4.813	2583	18.19
23.95	4.688	2264	17.26
27.04	4.563	1978	16.35
32.97	4.313	1492	14.61
38.55	4.063	1107	12.97
6 in. nominal size (outside diameter = 6.625″)			
9.29	6.357	10.38	31.7
11.66	6.287	9.82	31.0
12.39	6.265	9.65	30.8
12.93	6.249	9.53	30.7
14.99	6.187	9.07	30.1
17.02	6.125	8.62	29.5
18.78	6.071	8.25	28.9
18.98	6.065	8.21	28.9
25.04	5.875	7.00	27.1
28.58	5.761	6.35	26.1
32.71	5.625	5.63	24.9
36.40	5.501	5.04	23.8
45.30	5.189	3.76	21.1
53.17	4.897	2.82	18.8
8 in. nominal size (outside diameter = 8.625″)			
13.40	8.329	40.1	54.5
14.29	8.309	39.6	54.2
14.91	8.295	39.3	54.0
16.94	8.249	38.2	53.4
18.26	8.219	37.5	53.1
19.66	8.187	36.8	52.6
21.32	8.149	35.9	52.2
22.37	8.125	35.4	51.8
24.70	8.071	34.2	51.2
28.56	7.981	32.4	50.0
30.4	7.937	31.5	49.5
31.1	7.921	31.2	49.3
33.0	7.875	30.3	48.7
35.6	7.813	29.1	47.9
40.9	7.687	26.8	46.4
43.4	7.625	25.8	45.7
50.9	7.439	22.8	43.5
53.4	7.375	21.8	42.7
60.6	7.189	19.2	40.6
67.8	7.001	16.8	38.5
72.4	6.875	15.4	37.1
74.7	6.813	14.7	36.5
10 in. nominal size (outside diameter = 10.750″)			
18.7	10.420	123	85.3
21.2	10.374	120	84.5
22.9	10.344	118	84.0
24.7	10.310	116	83.5
28.0	10.250	113	82.5
31.2	10.192	110	81.6
34.2	10.136	107	80.7
38.7	10.054	103	79.4
40.5	10.020	101	78.9
43.7	9.960	98.0	77.9
54.7	9.750	88.1	74.7
58.0	9.687	85.3	73.7
64.3	9.564	80.0	71.8
76.9	9.314	70.1	68.1
80.1	9.250	67.7	67.2
89.2	9.064	61.2	64.5
104.1	8.750	51.3	60.1
109.9	8.625	47.7	58.4
115.7	8.500	44.4	56.7
12 in. nominal size (outside diameter = 12.750″)			
24.2	12.390	292	120.6
27.2	12.344	287	119.7
29.3	12.312	283	119.1
31.8	12.274	279	118.3
33.4	12.250	276	117.9
37.2	12.192	269	116.7
39.9	12.150	265	115.9
43.8	12.090	258	114.8
45.6	12.062	255	114.3
49.6	12.000	249	113.1
53.5	11.938	242	111.9
57.6	11.874	236	110.7
65.4	11.750	224	108.4
73.2	11.626	212	106.2
80.9	11.500	201	103.9
88.5	11.376	191	101.6
107.2	11.064	166	96.1
111.0	11.000	161	95.0
125.5	10.750	144	90.8
139.7	10.500	128	86.6
150.1	10.313	117	83.5
160.3	10.126	106	80.5
14 in. (outside diameter = 14.000″)			
27.7	13.624	469	145.8
32.4	13.560	458	144.4
35.0	13.524	452	143.6
36.7	13.500	448	143.1
45.7	13.375	428	140.5
54.6	13.250	408	137.9
59.0	13.188	399	136.6
63.4	13.124	389	135.3
67.8	13.062	380	134.0
72.1	13.000	371	132.7
84.9	12.814	345	129.0
89.3	12.750	337	127.7
93.5	12.688	329	126.4
106.1	12.500	305	122.7
130.8	12.125	262	115.5
150.7	11.814	230	109.6
170.2	11.500	201	103.9
181.6	11.313	185	100.5
189.1	11.188	175	98.3
16 in. (outside diameter = 16.000″)			
31.8	15.624	931	191.7
40.1	15.524	902	189.3
42.1	15.500	895	188.7
47.2	15.438	877	187.2
52.4	15.375	859	185.7
57.5	15.312	842	184.1
62.6	15.250	825	182.7
67.6	15.188	808	181.2
72.8	15.124	791	179.6
77.8	15.062	775	178.2
82.8	15.000	759	176.7
87.7	14.938	744	175.3
107.5	14.688	684	169.4
112.4	14.625	669	168.0
127.5	14.500	641	165.1
136.5	14.314	601	160.9
164.8	13.938	526	152.6
192.3	13.564	459	144.5
223.7	13.124	389	135.3
232.3	13.000	371	132.7
245.1	12.814	345	129.0
18 in. (outside diameter = 18.000″)			
47.4	17.500	1641	240.5
59.0	17.375	1584	237.1
70.6	17.250	1527	233.7
82.2	17.124	1472	230.3
93.5	17.000	1420	227.0
104.7	16.876	1369	223.7
110.4	16.813	1344	222.0
116.0	16.750	1318	220.4
132.5	16.564	1247	215.5
138.2	16.500	1223	213.8
149.2	16.375	1177	210.6
170.8	16.126	1090	204.2
208.0	15.688	950	193.3
244.2	15.250	825	182.7
274.3	14.876	728	173.8
294.0	14.625	669	168.0
308.5	14.438	627	163.7
20 in. (outside diameter = 20.000″)		Millions in.^{5}	
52.7	19.500	2.82	298.6
65.8	19.374	2.73	294.8
78.6	19.250	2.64	291.0
91.5	19.124	2.56	287.2
104.1	19.000	2.48	283.5
116.8	18.875	2.40	279.8
122.9	18.814	2.36	278.0
129.3	18.750	2.32	276.1
166.4	18.376	2.10	265.2
178.7	18.250	2.02	261.6
184.8	18.188	1.99	259.8
208.9	17.938	1.86	252.7
250.3	17.500	1.64	240.5
256.1	17.438	1.61	238.8
296.4	17.000	1.42	227.0
341.1	16.500	1.22	213.8
357.5	16.313	1.16	209.0
379.1	16.064	1.07	202.7
24 in. (outside diameter = 24.000″)			
63.4	23.500	7.17	434
78.9	23.376	6.98	429
94.6	23.250	6.79	425
110.1	23.125	6.61	420
125.5	23.000	6.44	415
140.7	22.876	6.26	411
156.0	22.750	6.09	406
171.1	22.626	5.93	402
186.3	22.500	5.77	398
238.1	22.064	5.23	382
252.9	21.938	5.08	378
296.4	21.564	4.66	365
367.4	20.938	4.02	344
429.4	20.376	3.51	326
483.2	19.876	3.10	310
509.7	19.625	2.91	302
542.0	19.314	2.69	293
30 in. (outside diameter = 30.000″)			
98.9	29.376	21.9	678
118.7	29.250	21.4	672
138.0	29.125	21.0	666
157.6	29.000	20.5	661
176.8	28.875	20.1	655
196.1	28.750	19.6	649

XUM

These pipelines depend on DE LAVAL *Centrifugal Compressors*



De Laval units, totaling 200,000 hp, are now in operation on major pipelines. Their 'round-the-clock dependability and efficiency are the reasons why De Laval Centrifugal Compressors have been chosen for so many booster stations. Consider these important design features • Pressure contact shaft seal eliminates gas leakage • Construction is heavy and rigid throughout • Units have high load carrying capacity • They can be designed to handle an increased ultimate flow.

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DL267

The Insulation Resistance Tester

. . . tool for electrical equipment maintenance

RICHARD W. INMAN

THE increasing use of electrical power and electrical equipment in the many phases of the petroleum industry in recent years has made the necessity for uninterrupted operation of great importance. In this regard, the industry is beginning to realize the economies of effective preventive maintenance programs on electrical equipment.

The most effective means of performing this job has been through periodic testing to predict the start of electrical equipment failure, rather than waiting until costly breakdown occurs. The indicator generally used in this "predictive" maintenance is the condition of the electrical insulation of the equipment in terms of its megohms of resistance. This means that the lower the insulation's resistance—the poorer a condition it is in—the more likely an electrical breakdown.

Insulation covering electrical equipment and wiring is to the eye, inert. Its dielectric properties (resistance to electrical current flow) are the reason for its use; and as good dielectric materials are also generally good wearing materials, the problem of weakening or faulty insulation may easily be disregarded until valuable equipment or critical wiring systems fail in use.

Actually, electrical insulation is subject to severe stresses even under normal operating conditions. These stresses, which cause progressive weakening of insulation value, are caused by heat, dirt, moisture, vibration, wear, aging, and even by light. During an on-off operation cycle of a motor for instance, the heating and cooling of the motor heats and cools the insulation over a wide range of temperatures. The mechanical strains thus set up in the insulation can eventually result in breaks causing direct short circuits or serious power losses.

Dirt, Humidity Are Enemies

Dirt is one of the greatest enemies of insulation because almost all casually collected dust, lint, grease, etc. is an excellent conductor and capable of penetrating minute cracks and faults in insulation. Keeping electrical equipment clean is thus a primary rule of preventive maintenance. Insulation resistance testing is the best means of detecting hidden dirt causing insulation deterioration.

Electrical equipment operating in a damp high humidity atmosphere requires added maintenance attention. The rising temperature of a starting motor for instance, allows the air around it to absorb more moisture; and a part of this moisture is absorbed by the insulation of the windings. On cooling, some of this moisture condenses on the insulation, and aids the expansion—contraction effects in deteriorating the insulation. Even a damp, high-humidity day creates this effect, lowering the insulation resistance of all electrical equipment. Of course, flooding or other accidental immersion of electrical apparatus calls for special treatment in dryng and cleaning.

EXCLUSIVE

Vibration is an ever present hazard wherever there is operating machinery, steam lines, etc. Insulation is subject to the same results from vibration as the automobile that "shook itself to pieces."

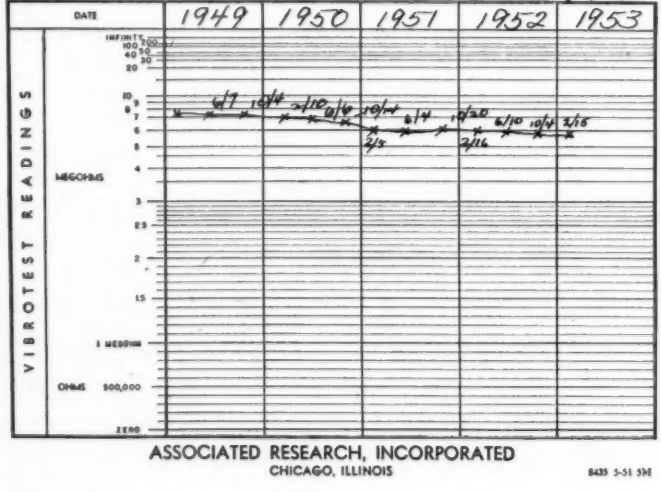
Wear, aging, and light deterioration are generally less severe than damage caused by dirt, water, heat, and vibration. All of them operate slowly, but still surely, in damaging insulation.

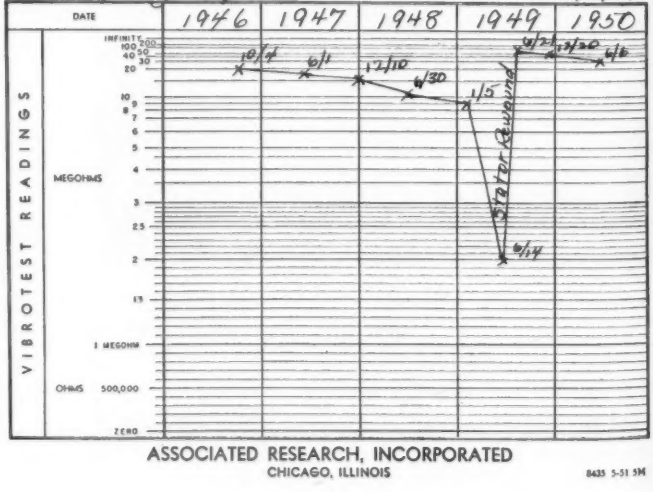
Finding "Weak" Spots

Because of these natural "enemies" of insulation, periodic checks with an insulation resistance tester will almost invariably predict breakdown or dangerous weakening of any part of electrical equipment or systems. As the effects of these "enemies" becomes greater, the resistance in megohms of the insulation decreases in value, eventually to a point of short circuit conditions unless the cause is found and checked.

There are several types of insulation resistance instruments available for periodic testing—ranging from the hand-cranked generator type to the push button operated, battery-powered type. This latter instrument has steadily proved to be one of the more conven-

FIG. 1. Periodic insulation resistance test records.





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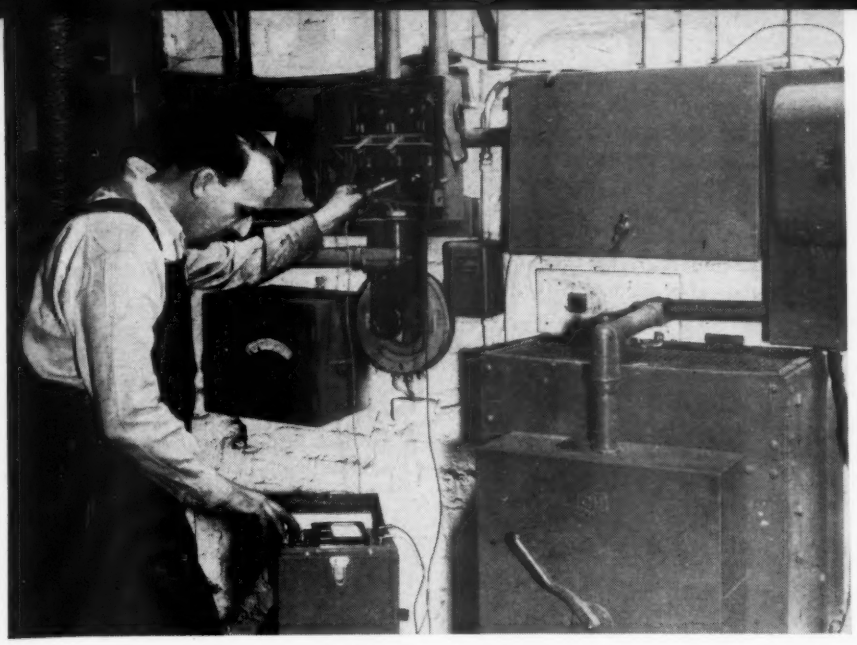


Testing network.

ient insulation testers because in addition to the megohm insulation resistance ranges, circuit checking ohm ranges and ac and dc voltage ranges are also available in the one instrument. These added scales are of great value as all too frequently circuits to be tested, though presumed to be dead, actually have operating voltages on them to the ground. Besides being dangerous to the test man, such conditions frequently damage the test instrument. These operating voltages on some electric generating equipment often reach 1200.

This instrument as described above derives its testing potential through a battery-powered synchronus vibrator power supply that is push button actuated. The testing potential of this and other insulation resistance testing instruments, normally 500 v dc, does vary for some types of tests and some ranges of resistance.

The megohm range gives a direct reading of the millions of ohms of resistance that any electrical insulation offers to the passage of current. Actually even good insulation does allow current to pass, if only on the order of 0.000001 amp, or less, per 500 v of impressed potential. It is this passage of minute current through insulation that causes the insulation resistance tester to indicate. During the resistance test, the insulation path being tested (between the instrument leads) is subjected to a potential of 125 to 1000 v dc depending upon the range and type of test instrument being used. This voltage causes a current flow through the insulation and through the indicating meter of the tester which is calibrated in megohms. Thus, actual resistance value is read as a result of the primary electrical formula:

$$R = \frac{E}{I}$$

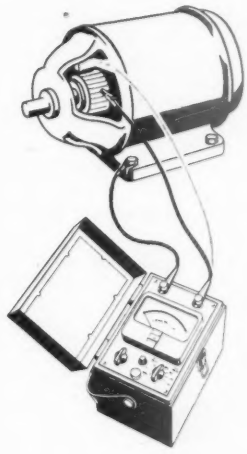
Unlike voltage, circuit resistance, or current flow, which can be determined positively at any given time with proper instruments, insulation resistance values that are "safe" for any piece of equipment vary greatly. Two motors, for example, of the same horsepower, same maker, and same age may have quite different insulation resistance values, yet both be in safe operating condition. Therefore, insulation resistance tests can do the best preventive maintenance job only if records are kept on each piece of equipment tested — and if tests are made at uniform intervals under similar conditions of operation, temperature, and humidity.

True, this may sound complicated as well as time consuming at first though, but the few minutes involved in the measurement and recording of resistance are minor compared with the saving in maintenance time should such troubles go undetected until an unexpected breakdown occurs.

An illustration of the value of insulation resistance test records is shown in Fig. 1. The chart at the left tells the continued story of a pump motor that is aging normally. Note that the first reading of 7.5 megohms was taken when the motor was installed new. Later readings taken at approximately equal intervals of four months, show a gradual, expected decrease in insulation resistance; but no sudden drops that would indicate future trouble.

The record at the right, however, tells the story of trouble with a happy ending. This motor was performing satisfactorily for the first two years, when a periodic check showed a sharp drop in insulation resistance to very close to the danger line. Inspection showed a need for a new stator winding, and after it was installed, resistance values bounced back higher than the first readings taken. Similar "case histories" could be shown for cables, circuit breakers, transformers, insulators, switches, meters, etc.

These cards are but two examples of the value of keeping track of the condition of electrical equipment and anticipating trouble in time to arrange for cleaning or repair without costly disruption of operations.



Methods of testing d-c motors.

With this discussion of what insulation resistance is and the importance of testing it properly and periodically, there is the question of just what is "good" insulation resistance? Safe insulation resistance in rotating machinery or other equipment may be regarded as that which is high enough to permit the equipment to operate normally without excessive current consumption or heating. This is the simplest, most obvious rule to follow if complicated formulas are to be

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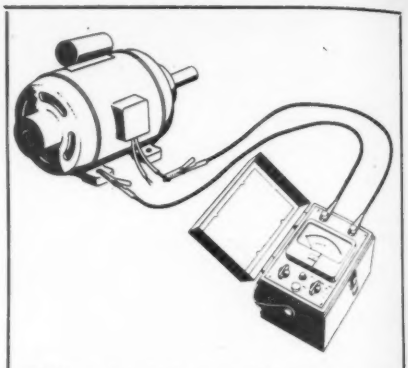
avoided. Generally, any insulation may be considered satisfactory in industrial equipment and circuits operating at 1000 v or less if its resistance exceeds one megohm at normal operating temperatures and humidities.

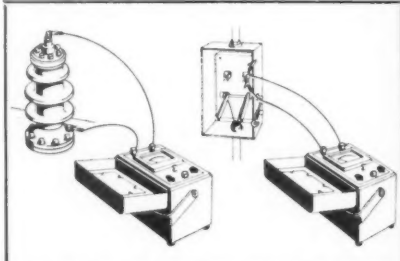
Carrying this safe minimum discussion a bit further, the safe minimum for apparatus operating in excess of 1000 v is simply one megohm for every 1000 v or fraction thereof. For equipment operating at 2500 v, for example, 2.5 to 3.0 megohms minimum resistance readings should be satisfactory. If initial insulation resistances fall below this "rule-of-thumb" minimum, equipment should be taken out of service, inspected carefully, and necessary cleaning or repairs made to bring resistance values over the minimum reading suggested.

At times, insulation develops weak spots that, under full working load and voltage, may have a tendency to cause serious internal current leakage or actual insulation breakdown. If the test voltage applied in making insulation resistance tests where this weakness exists is too far below the actual working voltage, there is a possibility that the test reading will appear satisfactory when it actually is not. Therefore in testing equipment that normally operates at voltages exceeding the instrument test voltage, it is well to increase the minimum value of acceptable resistance 1.5 to 2.0 times that of equipment operating at voltages lower than the test voltage of the instrument.



Testing insulation resistance on a-c motors.

Working electrical equipment such as motors, generators, transformers, heating elements, relays, etc., is more likely to develop insulation failure than static equipment such as wiring, insulators, and other non-moving, noncycling apparatus. Therefore, schedules of periodic insulation resistance tests should include more frequent testing of working equipment. Four to six months between tests is generally considered a safe interval. Some maintenance departments check all rotating machines every three months; and there are many motors operating in dirty or moist atmospheres that are checked monthly. Tests of wiring and like apparatus on a yearly basis are usually adequate unless working conditions are particularly bad.



Methods of testing insulators and switches.

This has necessarily been a rather brief and general consideration of the subject of electrical equipment maintenance with insulation resistance test instruments. Several more technical aspects of the subject, such as dielectric absorption testing and polarization index have been omitted. Nevertheless, choice of a good insulation resistance tester and employment of an adequate testing program will most surely bring about increased operating efficiency and relieve the headaches of sudden unexpected electrical breakdown. * * *

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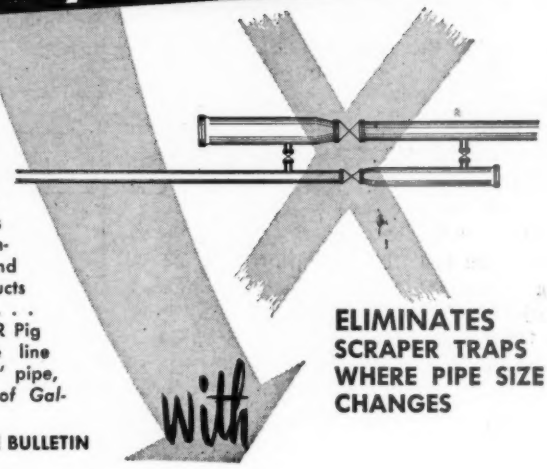

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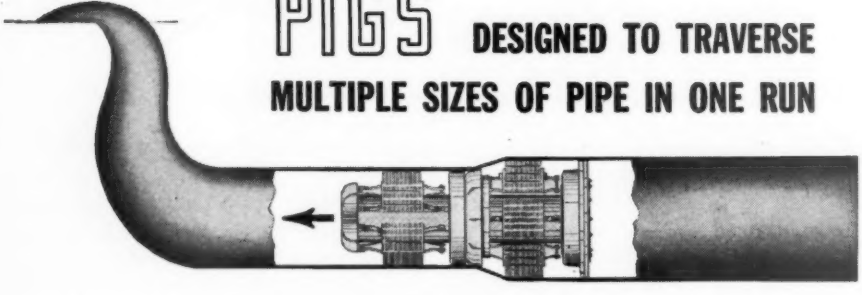

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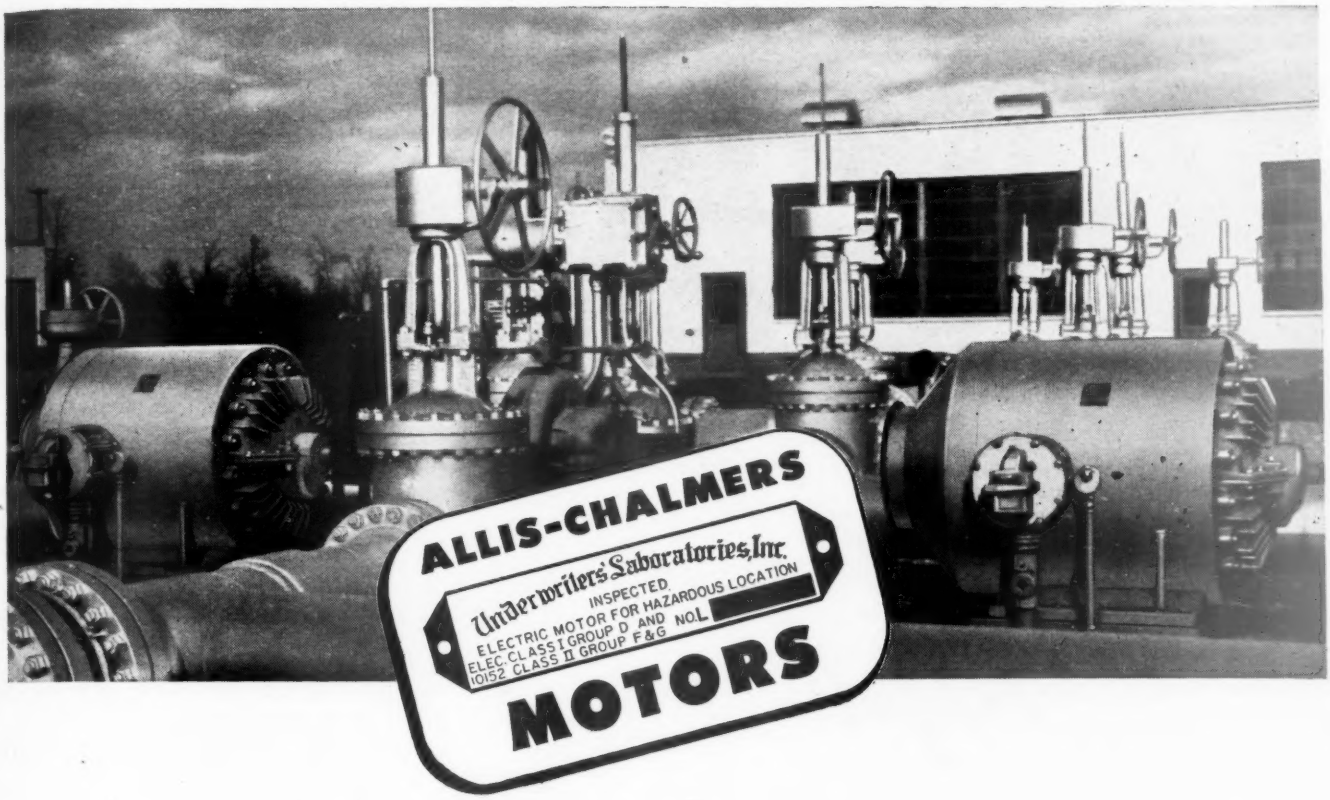

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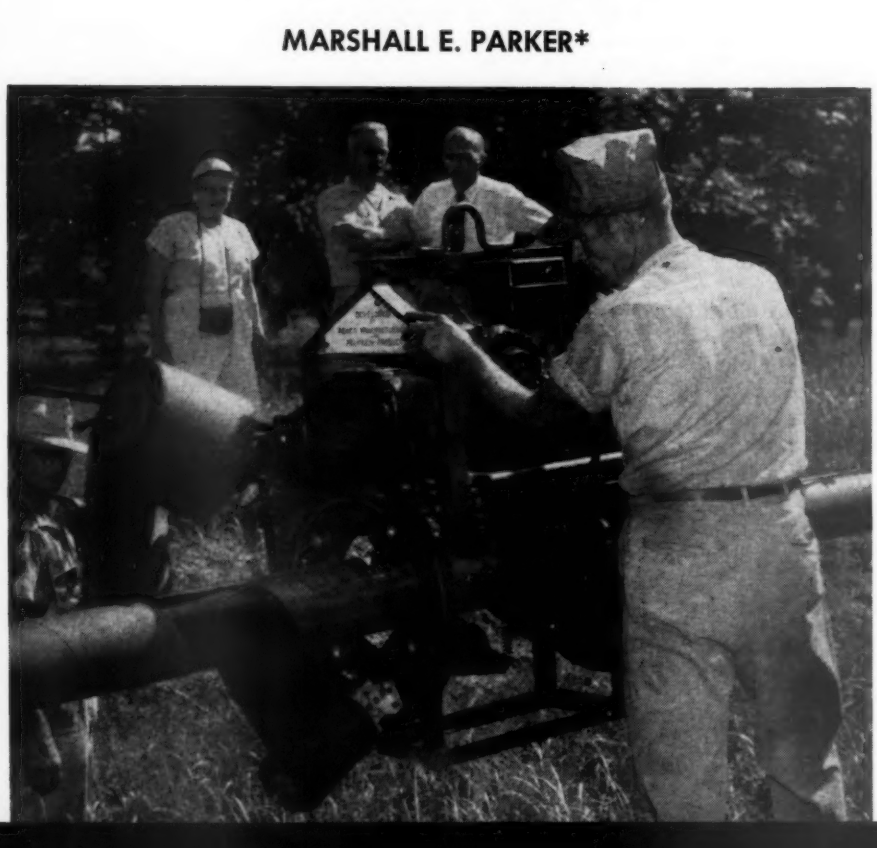
Applying protective tape coating to Seadrift pipe line, using modified hand-powered taping equipment.

Polyethylene *Tape* for Pipe Coating

. . . provides a new basis for design of cathodic protection systems

MARSHALL E. PARKER*



Latest advance in tape wrapping is this power-driven equipment. Speeds obtained are comparable with conventional coating methods.

SYNTHETIC materials have been developed in great variety in recent years, successfully competing with and replacing older "natural" substances, and in many cases, offering new properties for application to new uses. Inevitably such a development had to appear in the field of protective coating for underground pipe lines and similar structures. The material of choice is polyethylene, which is particularly appropriate, as it represents an opportunity for the oil and gas industry to return to one of its own products as a pipe coating material.

The form in which it is used is that of an oriented polyethylene film of 8 mils thickness, manufactured as a pressure-sensitive tape with an adhesive mass of 4 mils—a total thickness of 12 mils.[1] This material has a very high volume resistivity (low conductance), high dielectric strength, almost negligible moisture absorption, and excellent mechanical properties.

● As a pipe wrapping material, its obvious advantages are that it can be applied to any clean, dry, pipe without elaborate equipment—it can, in fact, be hand wrapped with no equipment at all. These properties combine to make it an attractive material for use on field joints, yard piping, service connections, and other small applications where the elimination of heating equipment and its associated hazards was advantageous.

For these applications, the behavior of the material in service can be deduced with sufficient accuracy and dependability from its measured properties. For long-line service, however, the conservative engineer is wary of accepting a new material on the basis of accelerated tests, or any small scale and short-time tests. A full-scale field test under actual service conditions is needed, at least in part due to the extreme complexity and unpredictability of the underground environment.

Such a full-scale field test has now been made, and the preliminary results are extremely encouraging. A section, 12.12 miles in length, of the Seadrift Pipeline Corporation's 65-mile, 8-in. gas line from Burnell to Seadrift, traversing Karnes, Refugio, and Calhoun counties, Texas, was wrapped with 8-in. tape and an outer, unbonded, wrap of tar-saturated asbestos pipe line felt.

*Consulting corrosion engineer, Houston, Texas.

[1]Polyken No. 900 Protective Tape Coating, manufactured by Kendall Company, Chicago, Illinois.

The section so treated lies wholly in Refugio County, in gumbo and caliche soil having an average resistivity of 1800 ohm-centimeters (maximum value observed at pipe depth, 2100; minimum, 1550.)

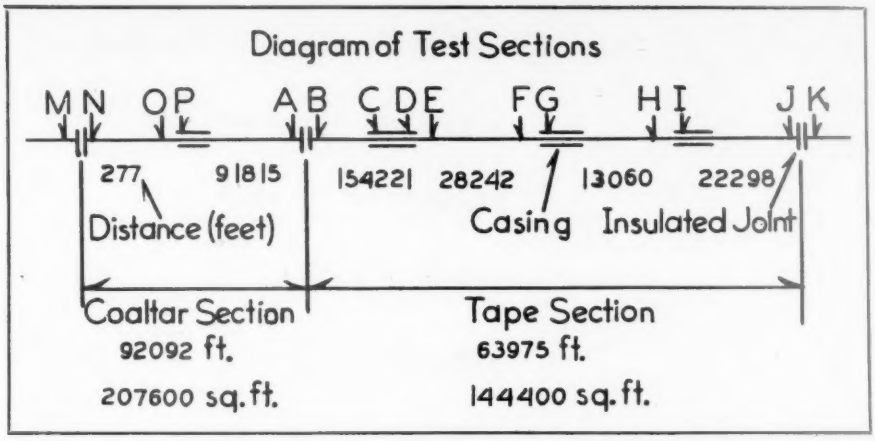
After the pipe had been welded into a continuous line, it was cleaned with a rotary cleaning machine that travelled the line on rubber-tired wheels. Following this, the tape and felt were applied with a manually-operated wrapping wrapping machine and the line lowered directly into the ditch. A single sideboom tractor cradled the pipe for all of the above operations.

The remainder of the line was coated with a conventional system, consisting of a coal tar primer, followed by a 3/32-in. coat of coaltar enamel with a bonded outer wrap of glass-reinforced felt. This system was applied in the usual manner, requiring 2 sets of operating equipment and 2 sideboom tractors for the operations starting with the welded line and ending with the coated line in the ditch. The 18-mile section immediately to the east of the Polyken section was isolated by insulated joints, as was the Polyken section, in order to facilitate a direct comparison of their performances. The soil in which this section lies is entirely comparable to that of the adjacent section; a maximum value of 2150 and a minimum of 1490 was observed, with the mean value approximately 1800.

The line was buried in February, 1954, both of the sections under study being completed by February 17. On March 29, the first of two surveys was made on the two sections, some 4 or 5 in. of rain having fallen in the interim. Thus it would appear that sufficient moisture and sufficient time had accumulated to yield valid data on the coating conductance and the current requirements.

Both of the sections tested were so short, and had such low conductance to remote earth, that no attempt was made to determine the extremely low values of line current flowing; all of the current measurements were those of total drainage current, measured with an ammeter in the drainage circuit itself. Small temporary ground beds were used, with a 6-v storage battery as the current source.

● Prior to the application of any test current, the pipe-to-soil potential was observed at each test lead, in order that polarization effects could be studied. The data taken during the test itself—pipe-to-soil potential with test current "off" and "on"—were such as to make possible the determination of total leakage conductance (usually called "coating conductance") as well as current requirements for cathodic protection.



A cathodic protection system for the line is now being designed, and its future performance will yield further data on the coating systems.

The field data are summarized in Tables 1 and 2. Table 3 gives the calculation of total leakage conductance. It will be seen that the attenuation, or diminution in driving voltage along the line, is so small that calculations based thereon are likely to be inaccurate; by the same token, calculations based on a direct arithmetic mean are reliable when the attenuation is so small; in other words, the line acts like an isolated piece of burned metal, the IR drops of the small line current floating being relatively inconsequential.

TABLE 1. Coating conductance and and current requirement tests.

Location	March 29, 1954 Pipe-to-soil potential			Driving voltage	Polarization potential
	Static	on	off		
B	598	1163	676	487	78
E	600	1162	678	484	78
F	575	1117	650	467	75
H	620	1155	693	462	73
J	612	1145	685	460	73
A	625	1017	805	212	180
O	644	1165	749	148	105
N	651	1211	768	146	117

All potentials are given in millivolts.
Test current: Tape section (B–J) 76 milliamperes
Coaltar section (A–N) 110 milliamperes

TABLE 2. Coating conductance and current requirement tests.

Location Static	July 6, 1954 Pipe-to-soil potential			Driving voltage	Polarization potential
	Static	on	off		
B	606	875	632	243	26
E	609	852	646	243	37
F	582	816	599	234	17
H	626	856	639	230	13
J	618	822	652	230	34
A	645	933	735	198	90
O	661	860	723	137	62
N	673	843	708	135	35

All potentials are given in millivolts
Test current: Tape section (B–J) 38 milliamperes
Coaltar section (A–N) 120 milliamperes

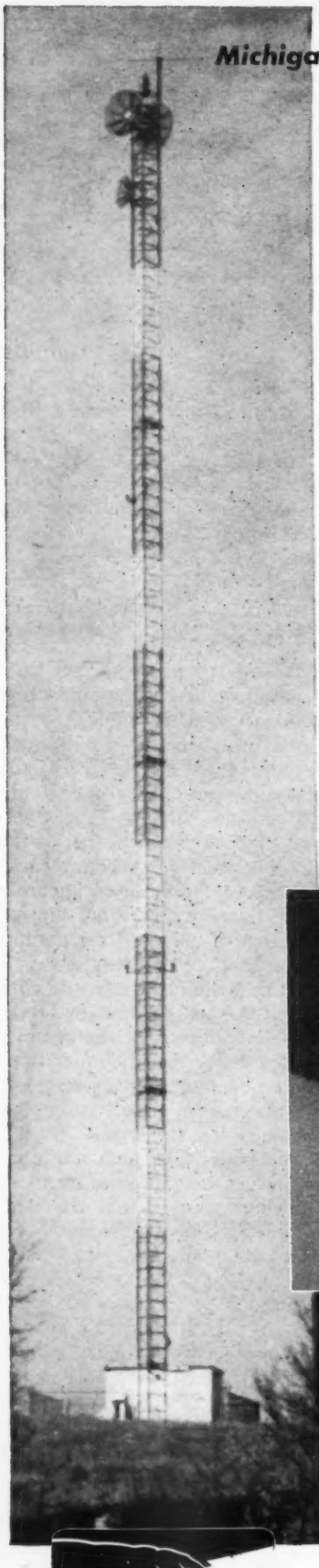
TABLE 3. Calculation of coating conductance.

Test 1, Tape section:	
Total current drained	= 76 milliamperes
Average driving voltage	= 472 millivolts
Input resistance = 472/76	= 6.22 ohms
	= 889,000 ohm-sq ft
	= 1.13 micromhos per sq ft
Test 1, Coaltar section:	
Total current drained	= 110 milliamperes
Average driving voltage	= 169 millivolts
Input resistance = 169/110	= 1.54 ohms
	= 318,000 ohm-sq ft
	= 3.15 micromhos per sq ft
Test 2, Tape section:	
Total current drained	= 38 milliamperes
Average driving voltage	= 236 millivolts
Input resistance = 236/38	= 6.22 ohms
	= 1.13 micromhos per sq ft
Total 2, Coaltar section:	
Total current drained	= 120 milliamperes
Average driving voltage	= 157 millivolts
Input resistance = 157/120	= 1.38 ohms
	= 3.52 micromhos per sq ft

● The conductance of the tape wrapped section is seen, in Table 3, to be about one third that of the enamel-coated section, when first tested; the later test shows no change in the conductance of the Polyken Tape Coating, but a slight increase in that of the enamel. (A very early test, before backfill consolidation, and involving only 3300 ft of tape-wrapped line, showed a conductance of only 0.01 micromhos per square foot, or virtually zero.) It is not felt that the change in the conductance of the enamel actually represents any deterioration of the coating; it is more probable that the much thinner Polyken coating, with its very low moisture absorption, simply reached a stable value in less time.

The implications of such low conductance values are twofold; first, there is the obvious gain in that the total amount of current required for cathodic protection will be less, and therefore will cost less. This is, however, a relatively minor gain, as the total cost for cathodic protection of the enamel section is not very large itself. A second, and less obvious, advantage, is the almost complete freedom from possible interference effects with other structures, because of the extremely low current densities involved, and the correlative advantage of a cathodic protection system which will be very easily monitored, and will be sensitive to any disturbances.

There is, moreover, another implication of still more far-reaching consequences implicit in this development of a coating system of exceedingly low conductance; it amounts almost to a new concept of the application of cathodic protection. When the current



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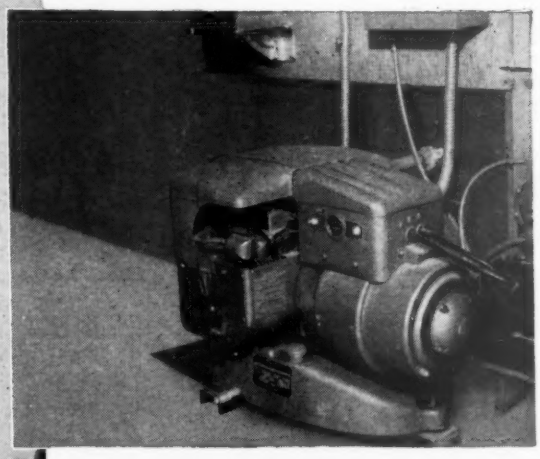
Onan Model 305CK shown installed in the repeater station at Waukesha, Wisconsin. Bottled gas is used for fuel.



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demands are so very low, it seems short-sighted to supply only the trifling quantities needed, without taking advantage of the situation to obtain more reliable protection.

This can be had by the installation of what is essentially a constant potential system, instead of the conventional constant current system. Then, if there occurs any significant damage to the coating (which will immediately result in a lowering of the effective resistance) there will automatically follow an increase in the current supplied, so as to maintain pipe-to-soil potential virtually constant.

This is made possible by the high resistance of the part of the circuit lying between the pipe metal and the earth—"remote earth" in the mathematical concept. With the coating system discussed, this resistance is so large that it can easily be made the controlling factor in the circuit. In other words, we have but to install a current source of low potential, but of intrinsically high current capacity, and we have a self-regulating system.

● For small diameter lines in low resistivity soil (up to about 10-in. diameter and 2000 ohm-cm) this can be done by using zinc anodes, installed in considerably greater number than needed for the indicated demand. For larger lines or higher resistivity soil, low-voltage rectifiers can be used with ample grounds—say, 2-volt 20-ampere units, with 0.2 ohm ground beds. The resistance of the coating will limit the current output to not more than 2 or 3 amperes, but the additional capacity will be available in case of need.

There is another advantage to this type of installation. Lines with low-conductance coatings are subject to accidentally impressed voltages from lightning surges (which do not necessarily involve direct strokes) and thus, for safety reasons, should be well grounded. A line with ordinary coating is well grounded—through the coating. But a line with superior coating is not, and grounding is needed for protection to equipment and to personnel. The use of zinc anodes as cathodic protection power sources also guarantees low-resistance grounding. The same is had (with proper design) with the rectifier systems above mentioned.

All in all, it seems clear that the development and application of this material makes possible the design of cathodic protection systems on an entirely new basis, with almost complete freedom from interference problems, and with a degree of automatic regulation hitherto unobtainable; new vistas of reliability and of low total cost maintenance are opened up for the progressive corrosion engineer. * * *

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Proper Planning of Compressor Plants

Conventional gas compressor plant worries and maintenance can be avoided through good physical arrangement and placement of component parts

H. S. FARNSWORTH*

THE compressor plant discussed in the following includes conventional gas-powered horizontal reciprocating compressors, requiring normal operating utilities.

Whether the plant is used for natural gas gathering, recycling or some of the many other services requiring gas compression, the fundamental operating conditions are generally the same.

One of the first and major considerations in planning a compressor plant is the engine-compressor foundation block. This structure, if properly designed and installed, may eliminate a large portion of the mechanical vibration so often present in compressor plants. Of particular note, in proportioning a well designed engine-compressor foundation, is the fact that the concrete block is shallow and wide, rather than high and narrow. This insures the minimum lever arm between the centerline of the horizontal forces of the compressor unit and the center of gravity of the concrete mass. (Fig. 1.)

Shallow blocks are not always possible or practical. This is particularly true where compressor house basements are indicated. In such cases, compensating design characteristics have to be emphasized. The minimizing of a large proportion of mechanical vibration at its source is usually possible, however, by the correct proportioning of the required mass in the foundation. The normal ratio of mass to the horizontal forces should increase as the height of the block increases.

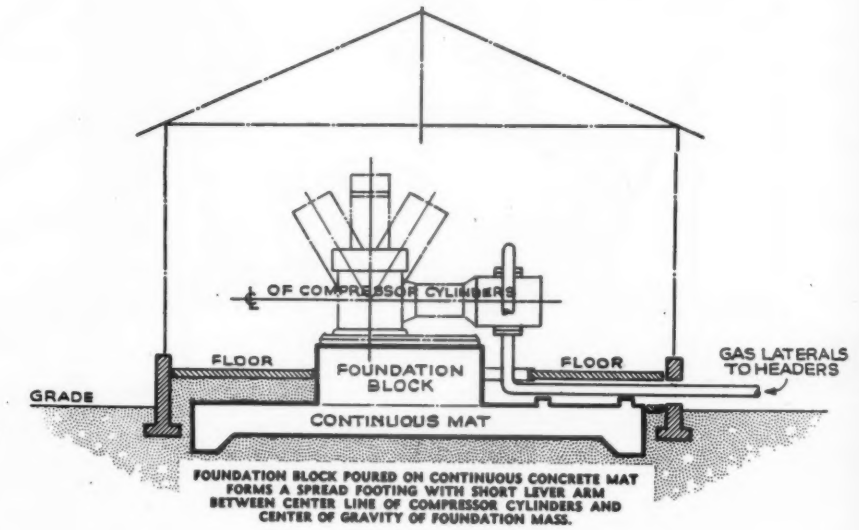

℄ OF COMPRESSOR CYLINDERS
FLOOR
FOUNDATION BLOCK
FLOOR
GAS LATERALS TO HEADERS
GRADE
CONTINUOUS MAT
FOUNDATION BLOCK POURED ON CONTINUOUS CONCRETE MAT FORMS A SPREAD FOOTING WITH SHORT LEVER ARM BETWEEN CENTER LINE OF COMPRESSOR CYLINDERS AND CENTER OF GRAVITY OF FOUNDATION MASS.
℄ OF COMPRESSOR CYLINDERS
FLOOR
FLOOR
GAS LATERALS TO HEADERS
GRADE
CONVENTIONAL FOUNDATION BLOCK
CONVENTIONAL FOUNDATION BLOCK HAVING GREATER DEPTH AND LESS STABILITY THAN THE SPREAD FOOTING SHOWN ABOVE.

FIG. 1. Comparison between a conventional engine-compressor foundation block and block poured on a continuous concrete mat.

Gas Piping

The piping system can be the source of many operating difficulties within a plant. Good planning may eliminate some of these troubles.

Operating block valves, such as those controlling the gas suction and discharge, should be placed close to the compressor units they serve, with the engine fuel and starting air valves conveniently close. These items are fundamental, yet the gas block valves are frequently located a great distance apart or at comparatively inaccessible points in the header area. This is particularly true in multiple-stage compressor systems. In view of such complex piping, careful planning is necessary to insure an easily operable arrangement of valves.

Where plug cocks are used, clearance should be provided for pulling the plug out of the body without removing the whole plug cock from the line.

One of the latest trends in gas plants and plants for similar industries is to run piping above ground and as close to grade as practical. This arrangement has many salient features; chief among these is the ease with which pipe runs may be secured to concrete sleepers, thereby tending to diminish any mechanical vibration. Many of the earlier compressor plants included overhead, loosely supported gas suction and discharge lines. These were frequently a source of annoyance and danger because of their excessive vibration and the difficulty in supporting them.

There is another type of vibration inherent in gas compressor systems.

Presented at CNGA Fall Meeting, Los Angeles, 1954.
*The Fluor Corporation, Ltd.

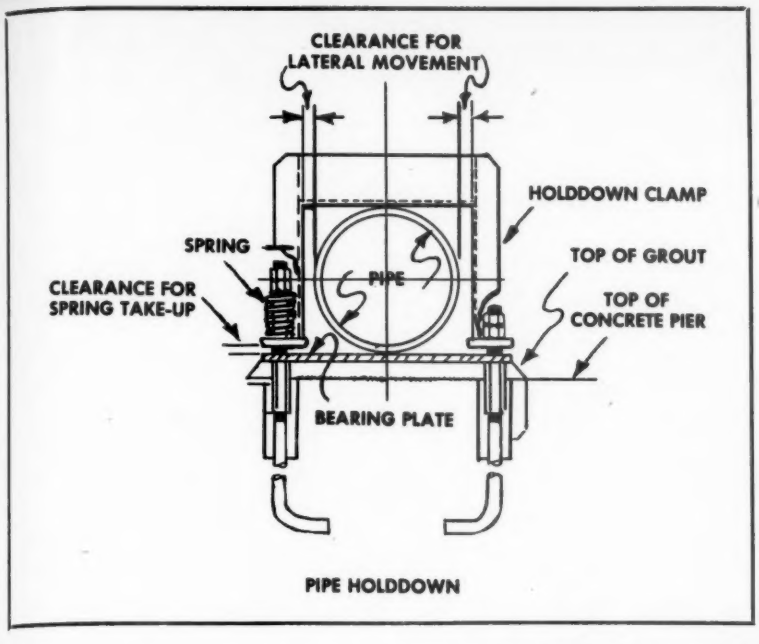
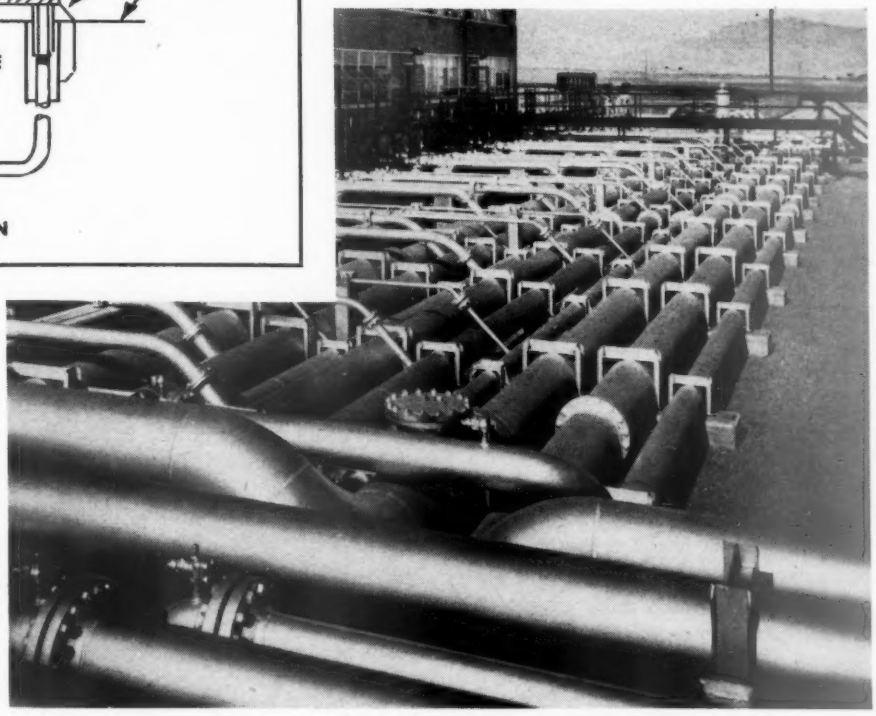


FIG. 2. Typical header system with "hold-down" clamps in place. Section of "holddown" detail is shown by insert.



This is manifested by pulsations in the gas flow. In most cases it is difficult to detect whether the vibrations existing in the piping system are caused by pulsations in the gas stream or by unbalanced mechanical forces. There are electronic instruments for detecting pulsations in flowing fluid and engineers specializing in this type of work.

It has been found that pulsations in the gas stream have been detected by "pinching" either the gas suction or discharge valves at the compressor cylinders, to take a pressure drop across the valve of about 10 per cent of the operating pressure. If there is no noticeable decrease in vibrations after applying the pinching operation as described above, it may be assumed that the vibrations are transferred from mechanical forces. Where two or more compressor cylinders are involved, the pinching operation must be performed on all the valves feeding from or into a common header.

Pulsative gas flow has several bad features in addition to the obvious structural difficulties arising from its vibration. These are:

1. *Difficulty in obtaining accurate orifice meter measurements.*
2. *Difficulty in control by conventional regulator valves.*

The usual methods of reducing pulsations in the gas stream are:

1. *Pulsation dampeners or pulsation dampening systems.*
2. *Adequately sized volume bottles.*
3. *Increasing the size of gas lines.*

Experience indicates that the only readily predictable means of reducing pulsations in the gas stream is to install pulsation dampeners designed and manufactured for this purpose.

An older means of reducing the effects of pressure pulsations is the increasing of pipe diameters. This is usually accompanied by the installation of volume bottles which are preferably connected to the compressor cylinders. Whereas, increasing the pipe sizes as a means of reducing gas velocities and effecting more rigid conduits, has, in many instances, eliminated vibration to some degree, it still has not always offered a positively predictable means of overcoming the vibration problem. This same condition also seems to hold true for volume bottles.

A complete scientific explanation is complicated but the simplest explanation is that the pulsation dampener must contain two elements, namely a volume and a restriction. The combination must be sized properly. In certain special cases improper proportions put the system in what is called resonance. With resonance the effects of pulsations are increased instead of decreased. This may be the reason that arbitrarily increasing the sizes of volume bottles may result in amplifying the problems associated with pulsations, rather than minimizing them.

The gas lines or headers, both on the suction and discharge sides of the compressor cylinders, should be adequately secured near the ground on piers of sufficient mass to absorb the transferred vibrations. The lateral lines between the compressor cylinders and gas headers are usually comparatively short and concrete piers extending up from the compressor foundation can be used in conjunction with the supports required outside the building.

Among numerous "hold-down" clamps used for securing pipe to piers is a proven device now manufactured by one company for this purpose. Fig. 2 shows a typical gas header system with "hold-down" clamps of this design in place, together with an insert showing the detailed model. Some of the main features of this clamp are that it has spring tension to allow longitudinal movement of the pipe and side clearance for lateral movement. The single spring also provides a certain amount of vibration damping.

If the plant consists of multiple compressors, the gas suction and discharge

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HOT DOPE

Straight from the Kettle on *PIPE PROTECTION*

★

By Boyd Mayes

Most times I agree that the shoemaker should stick to his last and pipe liners to pipe—but, since everybody is having his say on the FPC, gas transmission problems and price at the well head—feel it's fair to the public to remind 'em that all those words both pro and con which could confuse are covering up something *much more important than price issue*. As we see it—IT'S A MATTER OF PRINCIPLE or basic rights in business. We always figured that when a man got out of line—the law should get after him. But if he's a good member of the citizenry and disciplines himself—we never felt the law should lecture him. Seems to us somebody in the government was anticipating trouble—not waiting for any evidence of it. And we don't know of anything that regulates price better than competition between buyers and producers. Reckon that's somewhat the opinion of a lot of folks on this new problem.

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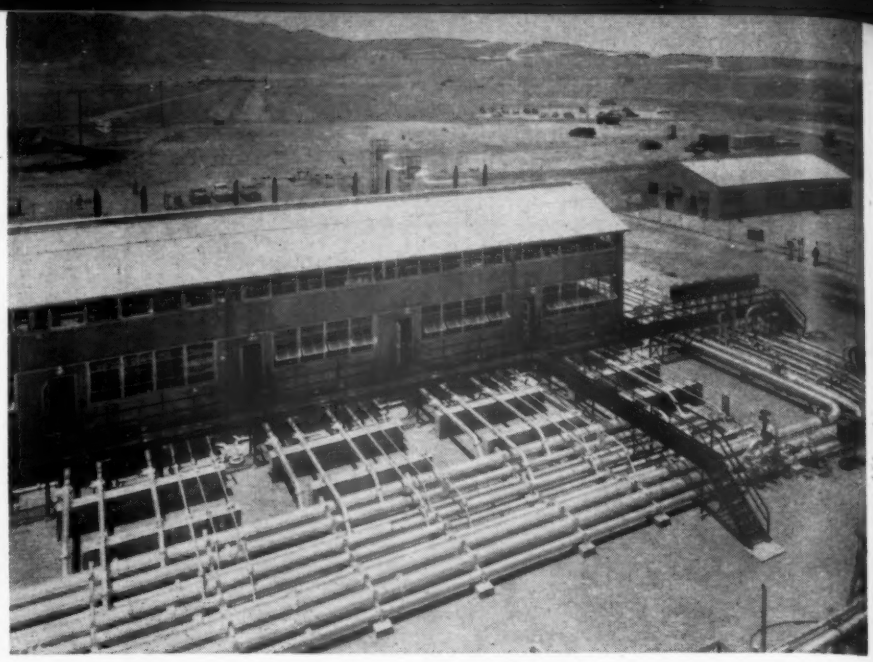

FIG. 3. Arrangement showing lateral gas lines connecting compressor units and header system.

headers are apt to be rather extensive in length. These headers are ordinarily outside the compressor building and they should be supported at intervals sufficient to reduce deflection to a practical minimum. (Fig. 3.)

A further consideration is the desirability of varying the pipe spans between supports to help reduce synchronous vibration. It has been suggested by Moerke and Newman that these supports be spaced at varying distances within a range of about 10 per cent above and below the calculated maximum span of pipe, so that adjacent spans will be supported by piers having different spacing. If the calculated span is 15 ft, the adjacent span could be about 16 ft on one side and 14 ft on the other side.

The subject of mechanical vibration, due to the movement of machine parts and pulsative forces in gas streams, has been a constant problem throughout the history of gas compressor design and operation. Several papers by M. L. Arnold, also N. H. Moerke and C. Newman have explored these problems with conclusions based on calculations and actual tests.

Linear expansion within the piping system, due to varying temperature, is a definite consideration. In many instances sufficient flexibility has to be provided in the piping runs in order to eliminate excessive stresses in the pipe. A typical example of this feature is found in planning the suction and discharge laterals between the compressor cylinders and the main gas headers of a multiple compressor plant. In such a case the gas headers would normally be anchored at the midpoint in length. During the period of startup, or a rise in the operating temperature of the flowing gas, the headers will expand in length away from the anchor points, with resultant bending in the lateral lines. Control of stresses may be accomplished by sufficient length pipe in the lateral lines, applied either as straight runs or as expansion bends.

Points at which gas lines having any degree of pressure are restrained in any way should be secured by clamps or u-bolts. This is in preference to clips welded to the pipe. If it is necessary to resort to welded clips on pressure lines, the applied stresses and design features should be carefully considered, since, as we have already stated, some degree of vibration is usually present in the gas system.

Adequate drain valves, properly located in the bottom of gas headers, are a very important requirement. The lack of these items often results in the accumulation of condensed liquids which can well carry over into the compressor cylinders, with dangerous results. This can conceivably happen in long intake headers between gas coolers and compressor cylinders, even though gas scrubbers are in place.

The low side of gas headers should be free from all types of ridges or obstructions to flow, such as welding slag and screwed pipe ends, that might cause condensate to collect. In such cases the condensate could be highly corrosive to steel pipe.

Common practice seems to indicate that the gas headers should be grouped on one side of the compressor building and the utility lines on the other side. This procedure helps to keep the gas header area free from possible obstructions in arranging a safe and operable gas piping system. The advantage is more pronounced in the case of

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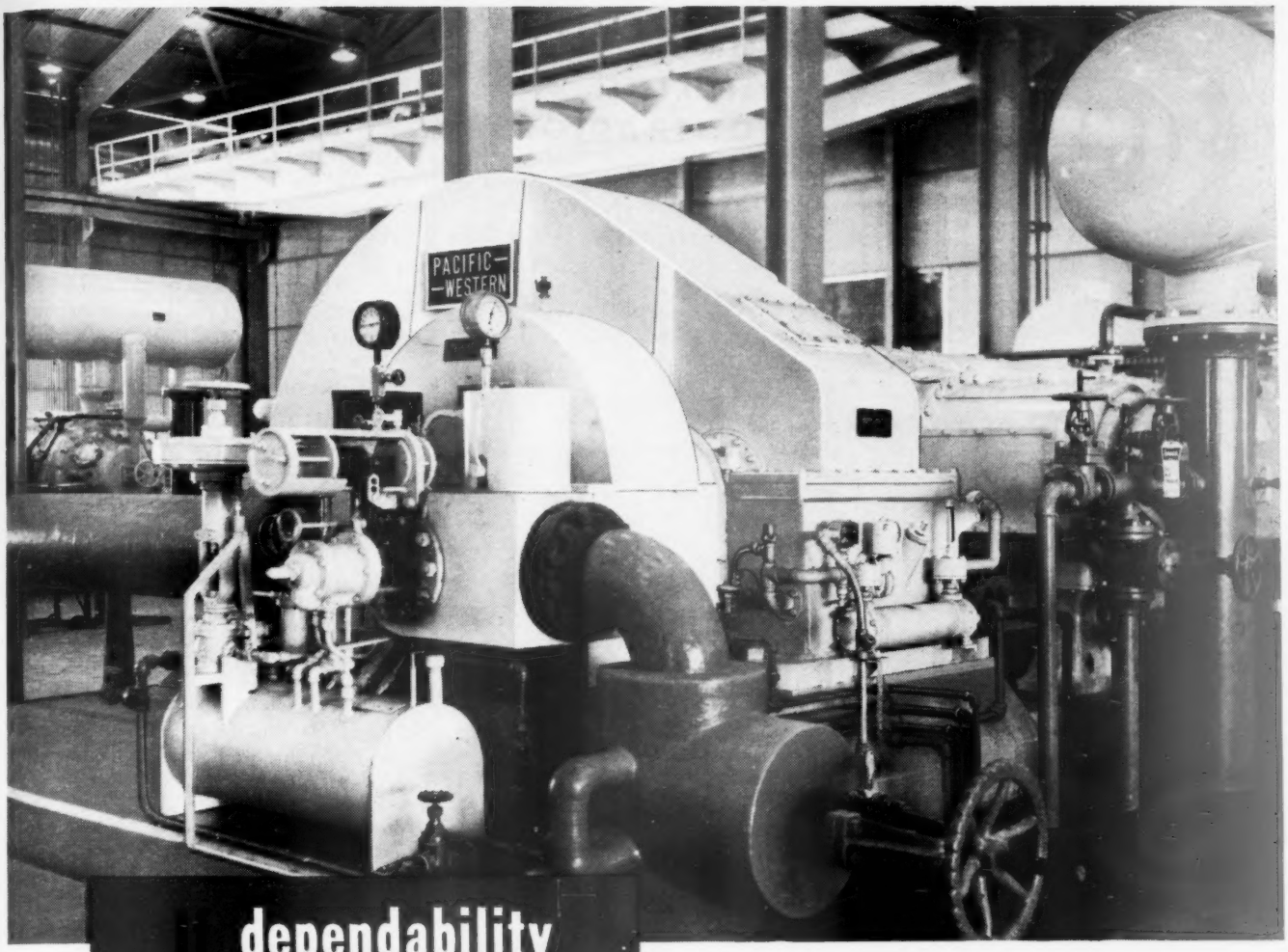

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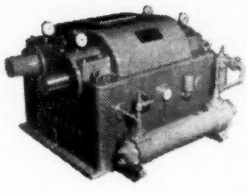
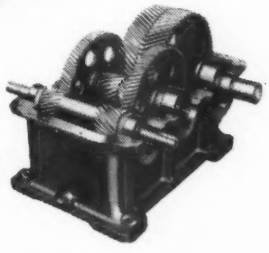


Custom-modified high speed unit



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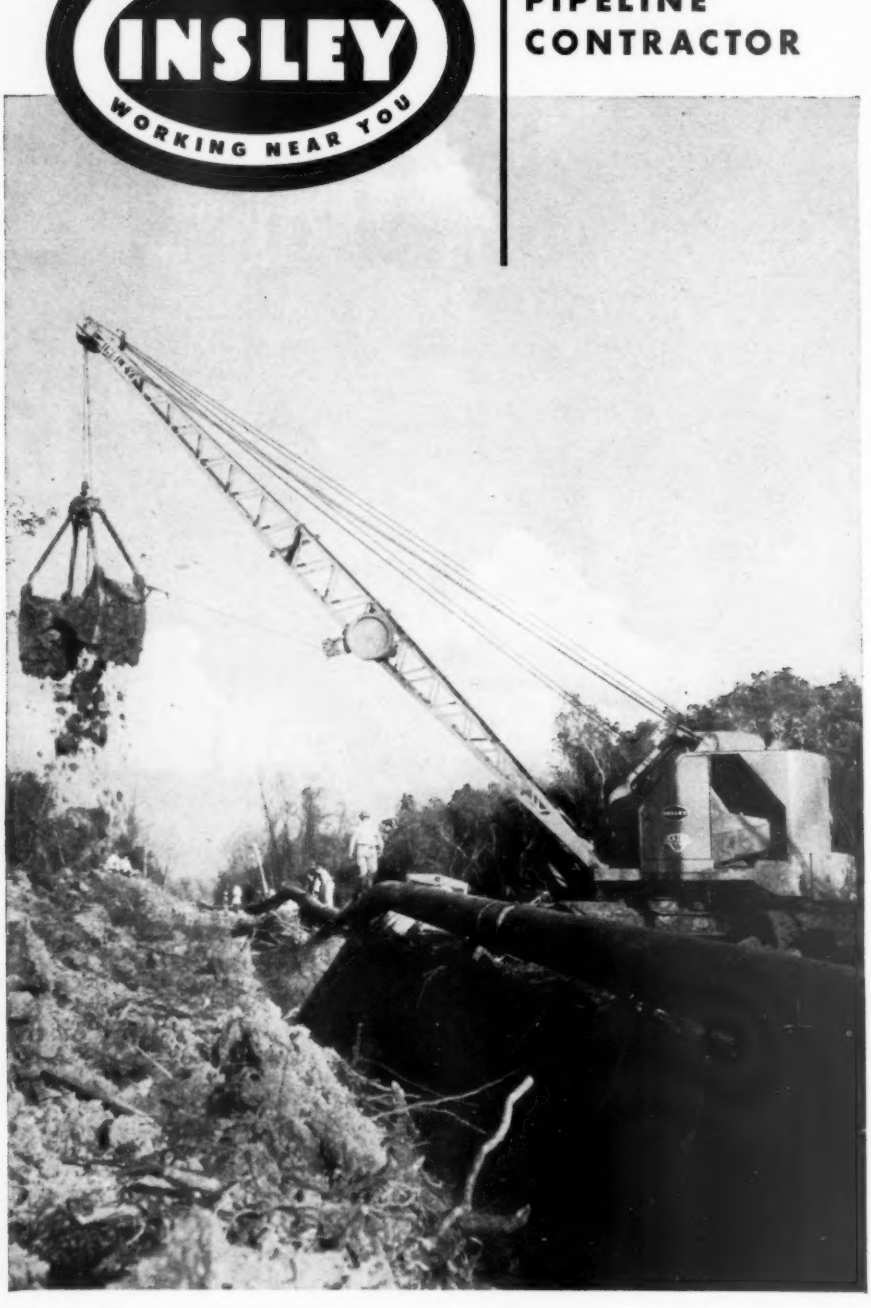

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A very important feature that may well be considered in planning the piping system is provision for "blowing-out" the gas headers before actual startup of the plant. This requires that all the gas headers be provided with blind flange ends where they would otherwise be blanked off with welding caps. An arrangement of this type allows the headers to be purged of slag and other foreign particles by exhausting air or gas through them.

Cooling Water System

During the days of the engine-compressors, having massive sections and slow moving parts, large streams of jacket water at comparatively low temperatures were used. During this period it was frequently the rule to use open cooling water systems. With the development of engines and compressors, tending toward greater speeds and higher jacket water temperatures, corrosion and jacket "scaling" have become greater considerations, until closed cooling water systems are now the rule. Our discussion considers this type of system.

The jacket water system is divided into the following cooling areas:

1. *Power cylinder jackets, including the exhaust manifold.*
2. *Compressor cylinder jackets.*
3. *Engine lubricating oil cooler.*

The consensus of opinion among engine manufacturers seems to indicate an average temperature of the cooling water to the power cylinder jackets from 145 F to 150 F and about 160 F from the jackets. A 10 F rise through the jackets is desirable with a maximum of 15 F rise. The more water circulated with minimum temperature rise results in less stress in the jacket walls and other parts of the engine.

The lube oil enters the engine at a temperature fairly close to that of the cooling water to the power cylinder jackets. For this reason the water to the oil cooler is somewhat colder than the water to the engine jackets. The difference in temperature of the water entering these two areas is more or less dependent on the size of the lube oil cooler and the quantity of water circulated through it.

The temperature of cooling water to the compressor cylinder jackets is usually close to that of the water entering the lube oil cooler.

Cooling water temperatures to the compressor cylinder jackets and the lubricating oil coolers vary considerably. Where the temperature of the water to these units is somewhere between 100 F and 130 F and the lube oil coolers are of average size, two jacket water streams are frequently used. This

arrangement includes one stream of water serving the lube oil cooler and compressor cylinder jackets in parallel with each other. Another stream of water is then circulated through the engine power cylinder jackets at an influent temperature of between 145 F and 150 F.

An alternative to this arrangement, still considering the same size oil cooler, is to circulate a single cooling water stream through all three cooling areas. In this latter case the water is circulated in parallel through the oil cooler and compressor cylinders, after which the total flow is recirculated through the engine power cylinder jackets and the temperature automatically controlled at the desired point. Of the two cooling arrangements described above, the former, employing two separate water streams, affords more positive temperature control. (Fig. 4.)

Another jacket water flow arrangement may be developed where higher compressor jacket water temperatures and larger lubricating oil coolers are used. This requires a shell and tube type cooler of sufficient size to circulate the full flow of jacket water needed by the engine power cylinders. In this case the jacket water is circulated in series through the lube oil cooler and engine jackets in the order named. Cooling water from the same stream is circulated through the compressor jackets in parallel. This arrangement is illustrated by Fig. 5.

A number of variations in the above systems are used. In some instances gas compression ratios are low, or, say less than two to one. Then circulating water through the compressor cylinder jackets is replaced by filling the jackets with oil or the use of air-cooled cylinders. The comparatively small amount of heat induced is dissipated through radiation.

The jacket water system should be arranged so that the least amount of water pressure is exerted against the cylinder head gaskets. This is accomplished by discharging the water directly from the jackets into a surge tank and then pumping through the water coolers to the lube oil cooler and back through the jackets. The surge tank should be vented to the atmosphere and carry cooling water level above the rest of the system. The circulating pump should be located close to the surge tank with a large suction line, free from bends, thus reducing the possibility of cavitation to a minimum.

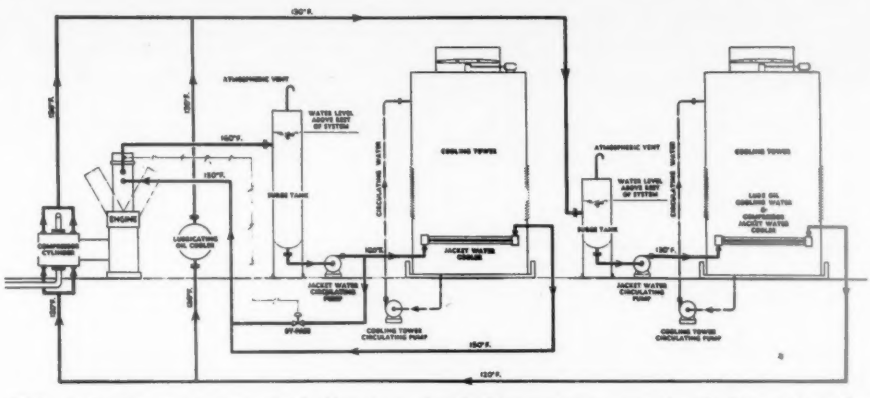

FIG. 4. Jacket water flow including two circulating systems, one circulating system for the engine power cylinder jackets and a colder system for the lube oil cooler and compressor cylinder jackets.

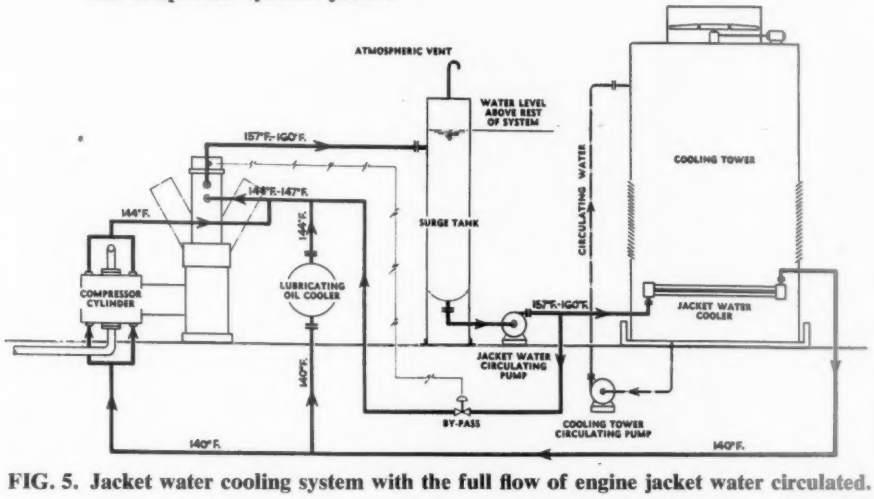

FIG. 5. Jacket water cooling system with the full flow of engine jacket water circulated.

Starting Air

Starting air at 250 psig is believed to constitute one of the operating hazards. This belief assumes that the lubricating oil, which is generally present in the air stream, is subject under some conditions to ignition from the heat of compression. The history of explosions in starting air systems of this pressure is sufficiently convincing to warrant extensive research and protective measures.

One means that has been considered logical in reducing this hazard is to circulate the air stream through a shell and tube type cooler on its way to the reservoir. A large proportion of the oil and water present may be knocked out in such a cooler, thus reducing the hazard from explosion as well as reducing operational troubles encountered as a result of water. Excessive water present in the air stream often makes starting difficult.

A check valve should be installed in the air line adjacent to the point at which it enters the power cylinder. This installation is definitely a requirement, since it constitutes a safeguard against flame entering the starting air line and igniting any oil which may be present. Sufficient storage capacity and adequately sized lines are very important requirements to be considered while planning the starting air system. (L. F. Scheel covered the air volume requirements in "Development of Gas Engine Compressor Plants," which appeared in the December, 1954, issue of *The Petroleum Engineer*.)

Exhaust System

The exhaust line from the engine through the muffler presents a hazard at times. This is in the form of exhausted fuel gas which has not been ignited. During a shutdown period, leaky valves may allow fuel gas to collect in the exhaust line. False-starts may also produce the same effect.

When the engine is started this gas is ignited, causing an explosion. Heavily constructed mufflers installed in a vertical position have a tendency to help purge the system of pocketed gas

The Author

Henry S. Farnsworth is a project engineer with The Fluor Corporation, Ltd., and has been engaged in the design and construction of various types of gasoline extraction and refining units as well as natural gas compressor plants.

Previous to his capacity as a project engineer, Farnsworth also served for a number of years as field engineer with the same company.

and offer resistance to minor explosions. A more positive means of purging this system of gas pockets is to install an air jet in the line close to where it leaves the engine. This arrangement allows the operator to blow-out the exhaust system just before starting the engine.

Apart from the hazards described above, it is possible to utilize the exhaust stream for useful work in the improvement of operating conditions. This is accomplished by the installation of air-cooled mufflers which draw the heated air away from around the engine area.

Safety Considerations

At least one state safety code requires that blinds be located in gas lines to and from compressor cylinders in cases where there is any question concerning the tightness of the block valves. The conservative decision usually includes blinds for the protection of anyone working in or around the compressor cylinder. The same provision applies to gas scrubbers or similar units of equipment.

Shut-off valves should be located in the main gas inlet and outlet lines at a safe distance from the engine-compressor units. The preferable location for these valves is the plant boundary. The conventional method of shut-off is by air-actuated remote control from a central station located at a safe and convenient point. Some of the safety codes require that these shut-off valves be located at a safe distance from the plant or major equipment. By observing the interpretation of the term "safe distance" in several plants, 300 ft seems to be the rule.

High liquid level alarms should be placed on all gas scrubbers to protect the compressors from liquid carry-over. These alarms are usually float-operated and connected to an electric relay for actuating an alarm or shutting down the compressor units.

The following are some of the precautions employed to safeguard personnel from lethal gases in the compressor system:

- **Air blower and necessary duct** work located in the compressor house. This produces a positive circulation of air throughout the length of the building sufficient to sweep any accumulation of gases out of the building through the pipe trenches.
- **Double block valves and bleeders** in gas lines to and from compressor cylinders. The bleeder is placed between the block valves.
- **Air ejector type evacuators are** installed at each machine taking suction from the distance piece between the crank case and compressor cylinder for the purpose of creating negative pressure around the piston rod packing.
- **Gas analyzer installed with connections** at each compressor cylinder and all other critical points.

The problems discussed are not assumed by any means to cover all the difficulties encountered in the average compressor plant. If these items are given due consideration, however, it it believed that much may be accomplished toward planning a satisfactorily operating plant.

The writer wishes to acknowledge the assistance of the following in contributing to the preparation of this paper: L. F. Scheel, E. J. Flavin, A. M. Whistler, N. H. Moerke, and C. Newman.

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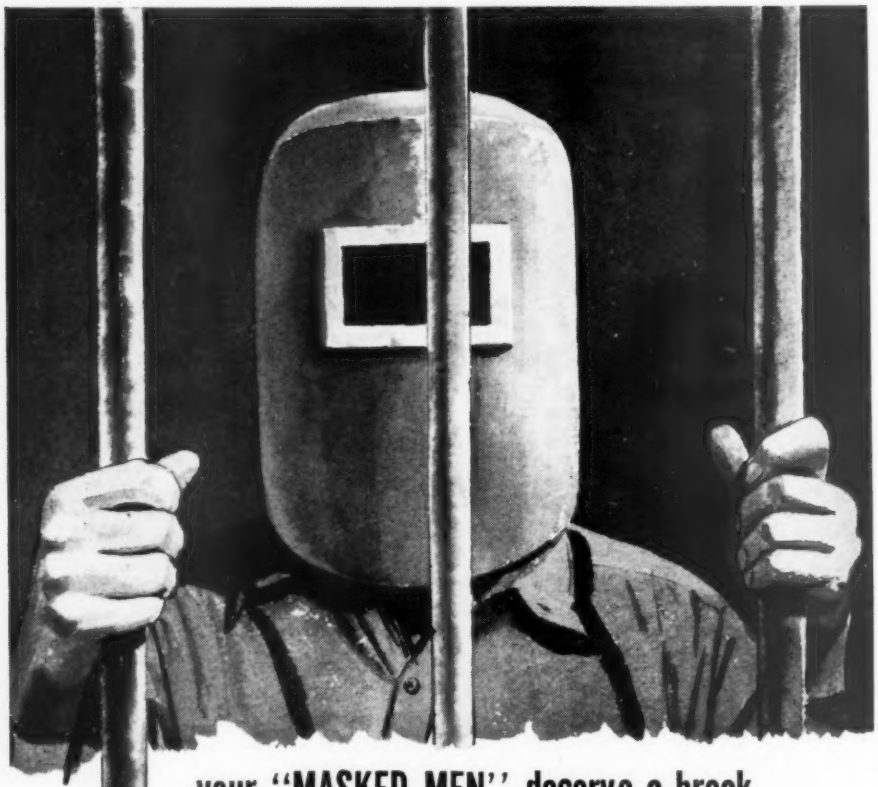

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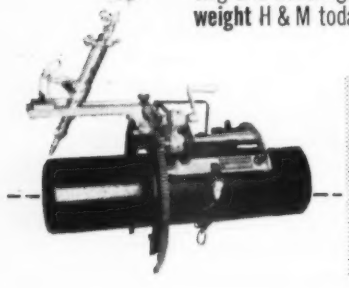

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View of Susquehanna crossing from west side. Dragline is excavating blasted material from trench for 24-in. line.

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Pipe Line vs. The Susquehanna River . . .

mile long crossing drilled through rock

Twin trenches, 10-ft deep, cut through stream bed for Texas Eastern-Penn Jersey line in Pennsylvania

C. H. VIVIAN*

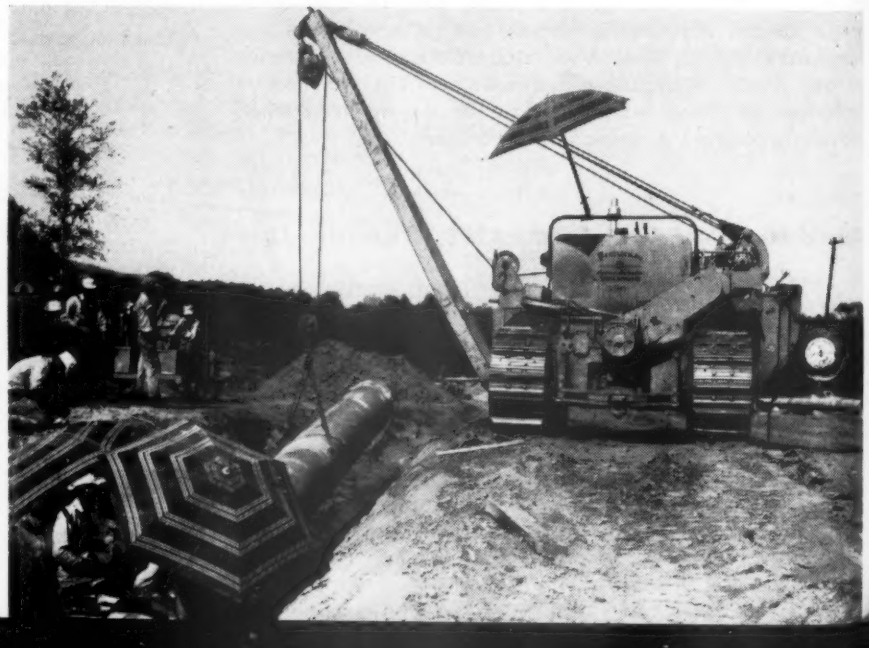
THE Susquehanna, which crosses eastern Pennsylvania in a generally north and south direction and empties into Chesapeake Bay in Maryland, is wide and relatively shallow throughout much of its course.

During the past summer it was unusually low because of a record-breaking drought, and this circumstance produced some strange conditions for the contracting firm of Pentzien, Inc., of Omaha, Nebraska, which installed dual lines across the stream for Texas Eastern Penn-Jersey Transmission Corporation. Late in August, for instance, the stream was so shallow that drill barges were moved around by crawler-mounted tractors running on the water bed, and men in a hurry simply rolled up their trousers and walked out to the working sites. Then there came a day when the boats could no longer float, and the small amount of drilling that remained was done by conventional twin drills hung from side-boom tractors.

The 265-mile line will extend from the Oakford storage field near Delmont, Pennsylvania, 35 miles from Pittsburgh, to a point near Lambertville, New Jersey, where it will connect with the main Texas Eastern Transmission Corporation pipe line that runs from Texas to New York City. The new line is 24-in. diameter, except at river crossings, where an additional 16-in. line was laid as a precaution in case one of them should break. Four other major river crossings besides the Susquehanna are involved in the project. Two of them, the Conemaugh and the Juniata, were contracted to Pentzien, Inc., and the others, the Schuylkill and the Delaware, were awarded to the Missouri Valley Dredging Company.

From valve headers on both banks, where the dual subaqueous sections tie in with the single overland conduit, the Susquehanna crossing is 5936 ft long, well over a mile. All but a few hundred feet of it on each side and a short stretch across a small island near the center of the stream is underwater, the river at that point measuring 5062

Tieing-in a joint of riverpipe on east bank.



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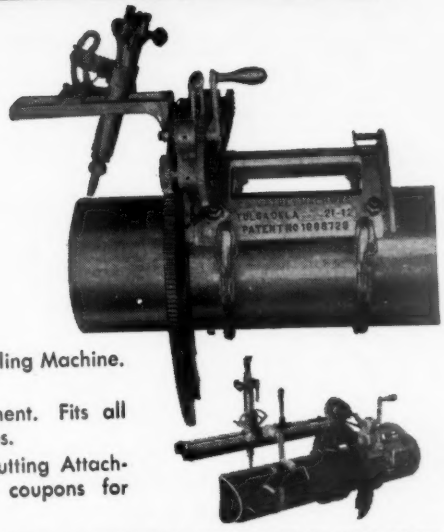

Illustrated above: Mathey Pipe Cutting and Beveling Machine. Cuts pipe at any predetermined angle.

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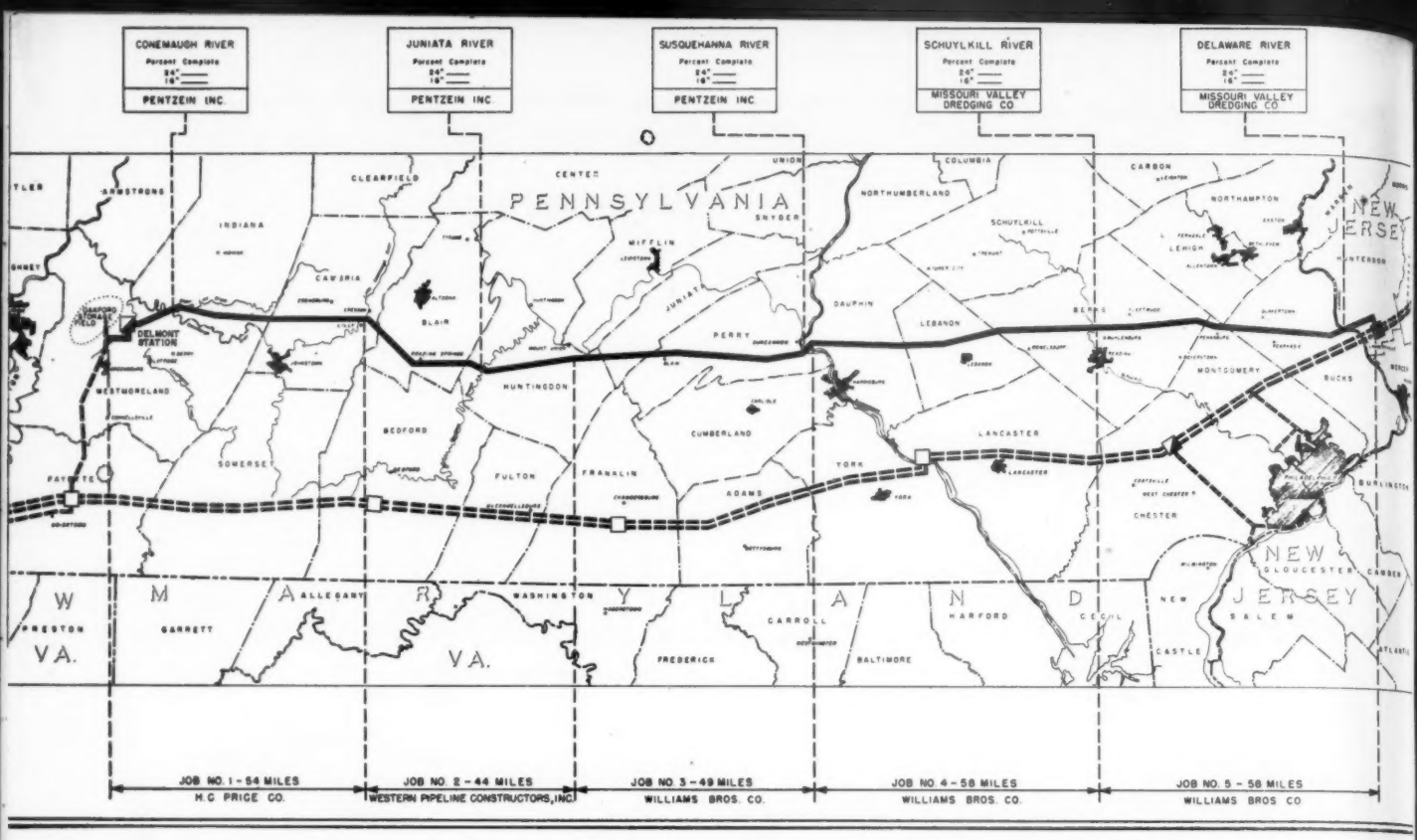


Solid line at top of map shows route of 265-mile, 24-in. line between Oakford storage field near Pittsburgh and connection with Texas Eastern's main line (broken double line on map) near Lambertville, New Jersey.

During low water periods, shot hole loaders waded in stream bed.

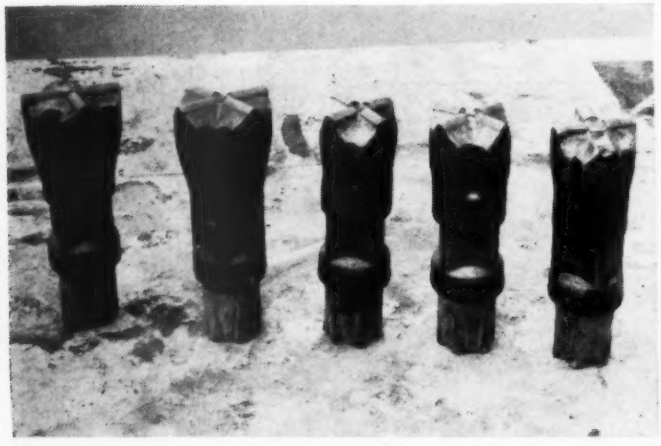
ft from high bank to high bank. The two lines occupy individual trenches, separated by 50 ft, with the 16-in. branch downstream. The general scheme was to excavate the trenches, pull the pipe into place and then backfill the openings. Specifications called for a minimum of 3 ft of coverage, and, to be on the safe side, the contractor drilled the blast-holes an average depth of 10 ft and a maximum of 14 ft.

About June 1, the water averaged 5 feet deep in the working zone. As the bottom consisted of rock, with little or no overburden in most places, drilling and blasting were mandatory, and the company decided to do the drilling from floating equipment of its own design and construction.

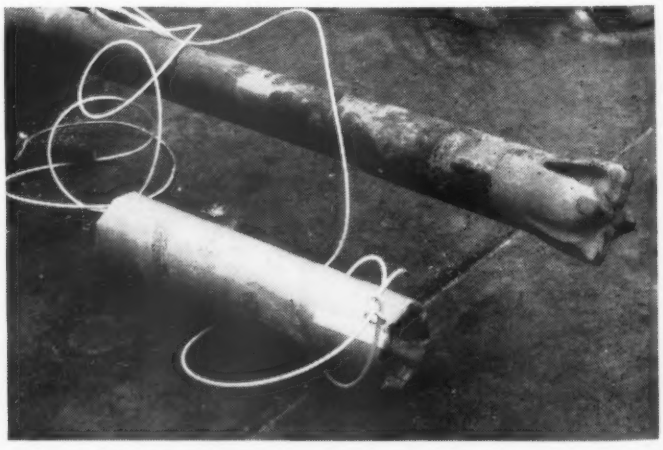
Two barges were built and equipped, each with a different machine. Most of the work was done by the one carrying an air-powered piston-type submarine drill, which is essentially a modern but smaller version of the units that achieved their first success on Panama Canal drill boats.

The newer type submarine drill is an adaptation of one designed a few years ago. It has a 6½-in. bore and 10-in. stroke, strikes 200 blows a minute, and can use 4¾-, 5½- or 6-in. bits.

Experience has shown that the piston drill is better adapted for submarine work than the newer, faster-striking hammer drill which serves almost universally for small-hole blast drilling. In the case of the latter unit, which ordinarily employs drill steel not more than 2-in. in diameter, the relatively small



Bits after drilling a collective 2 miles of holes in river bed. All were worn down approximately ¾-in.



New 5½-in. bit attached to hollow drill rod. Below it is one of 4½ by 22-in. dynamite cartridges used for blasting.

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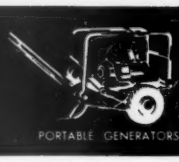
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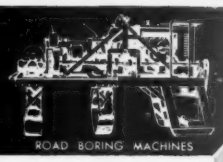
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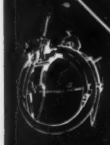
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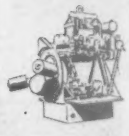
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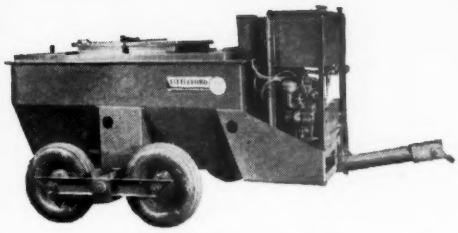
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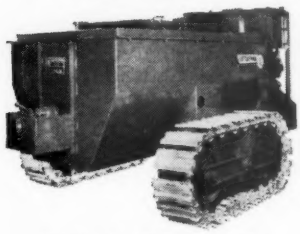
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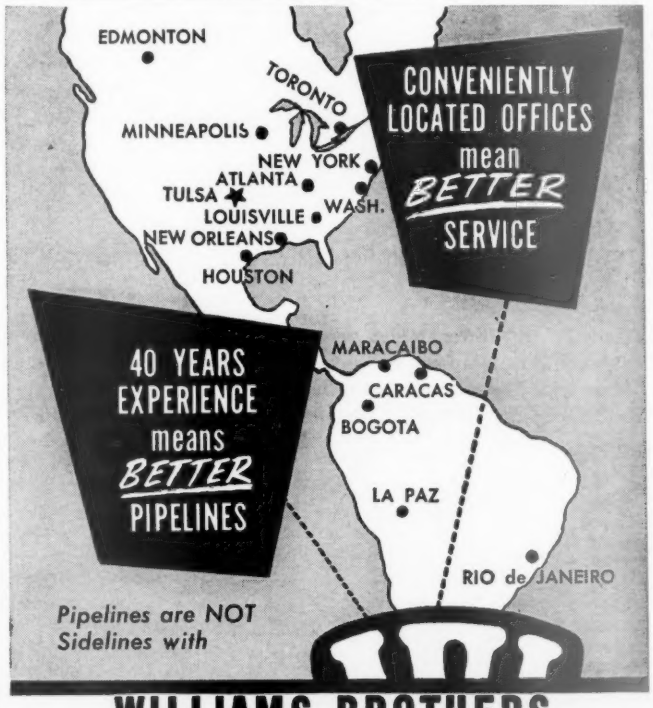

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Drill barge at work. Water level was so low that tractor with winch was needed to move boat between drilling points. In foreground are casings through which shot holes were loaded.

bit tends to slither around and slip off boulders when they are encountered and, hence, to bind in the hole.

Then, too, if sand or pebbles get into the hole, the steel often becomes stuck and is difficult to extract. On the other hand, the piston drill, with its large-diameter reciprocating rod and attached bit, works with a punching motion that seems to grind up material beneath and behind it. The whole assembly is sturdy enough to take the punishment without damage.

On the Susquehanna crossing job, the drill was mounted on a heavy slabback that traveled up and down on a 35-ft structural steel tower. The barge, measuring 21 by 53 ft, was composed of 6 steel-plate pontoons, each 7 ft wide, 26½ ft long and 3½ ft deep. These were assembled in 3 tandem groups joined together, side by side, with steel pins run through matching steel-plate "ears" working on the principle of old-style railroad-car couplings.

About 6 ft of the forward end of the central pontoon section was cut off to form a block, U-shaped recess. The tower was erected at the edge of the base of the U, and planks laid across the opening in front of the drill and supported by the flanking pontoons provided a working platform for the drillers.

As accompanying photographs show, the tower was trunnion-mounted so it could be pulled down and laid in horizontal position. The slabback and drill served as counterweights, and the weight was distributed with such precision that the tower was almost in perfect balance on the trunnion. In addition, the base was set on horizontal steel members or skids by means of which the entire assembly could be readily moved from the barge and loaded on a truck or railroad car for transportation to another job.

At the base and just back of the tower were two air hoists: A large unit that raised and lowered the slabback and drill and a smaller one that handled drill steel, sand pipe, etc. A 500-cfm diesel engine-driven compressor stationed aft on the boat supplied operating air for the drill and hoists.

The barge was equipped with spuds, one at each forward corner, and these were lowered to the water bed to keep that end steady for drilling. Provision for holding the floating platform against the current and for moving it consisted of three wire ropes: Two extending from the bow and one from the stern to points on shore or to "deadmen" set in the river at suitable places. These lines were run on and off their respective drums on a gasoline engine-powered winch.

Because of the low and continually falling water level, however, it was not necessary to use this gear to any extent or to resort to one of two available small steel-hull boats propelled by outboard motors. Instead, it was possible for a bulldozer with a rear-end winch to travel the stream bed, and that machine was utilized much of the time to nudge the barge the short distance between hole locations. It also pushed a lot of the overburden and loose rock out of the paths of the drill rigs.

Trenching was started on the east bank and carried out as far as the island near the center of the stream. The crews then moved to the west bank and again worked towards the middle. In the beginning, the trench for the 16-in. pipe was excavated first. Some of the broken rock was deposited downstream in a ridge and the remainder was cast upstream and then leveled off with bulldozers to form a slightly inundated road to serve as a haulageway for equipment and as a working base in digging the upstream trench. The plan had to be modified later when the time limit for completing the 24-in. branch was moved ahead.

Holes for each trench were drilled in 2 parallel rows spaced 42-in. apart. Those in each line were also normally spaced on 42-in. centers and staggered in relation to those in the neighboring line. When drilling, the bit worked inside a piece of 7-in. sand pipe that rested on the river bed and was long

Details of drill tower, which was hinged on a trunnion on the structural-steel base so that it could be laid back in a horizontal position, shown below. In right foreground is a 3-drum winch used to maneuver barge by means of wire ropes running to shore points or "deadmen" in river. Behind winch is 500 cfm air compressor used to supply air for drill and tower hoists.

enough to extend above the water surface. This kept sand and gravel out of the hole. After drilling was completed, the bit was withdrawn and a length of 5½-in. casing was lowered inside the larger one and bottomed partly in the hole, a few blows on top of it with the drill bit forcing it down to insure a secure fit. The hole was later loaded with powder through this casing, which was then removed with the aid of a line from the small air hoist.

In the area under consideration, the Susquehanna crosses many miles of successive ridges of the Appalachian Mountains at a considerable angle, forming one gap after another. The ridges are composed mainly of alternating layers of various sedimentary rocks that have undergone folding and structural changes as a result of long geological processes. On the river bed, narrow bands of the more resistant formations rise a little higher than the softer intervening material and are naturally the first to be exposed when the flow of water decreases. These strata dip at an angle of around 60 deg from the horizontal, and the pipe line intersects them at a slight angle to their strike.

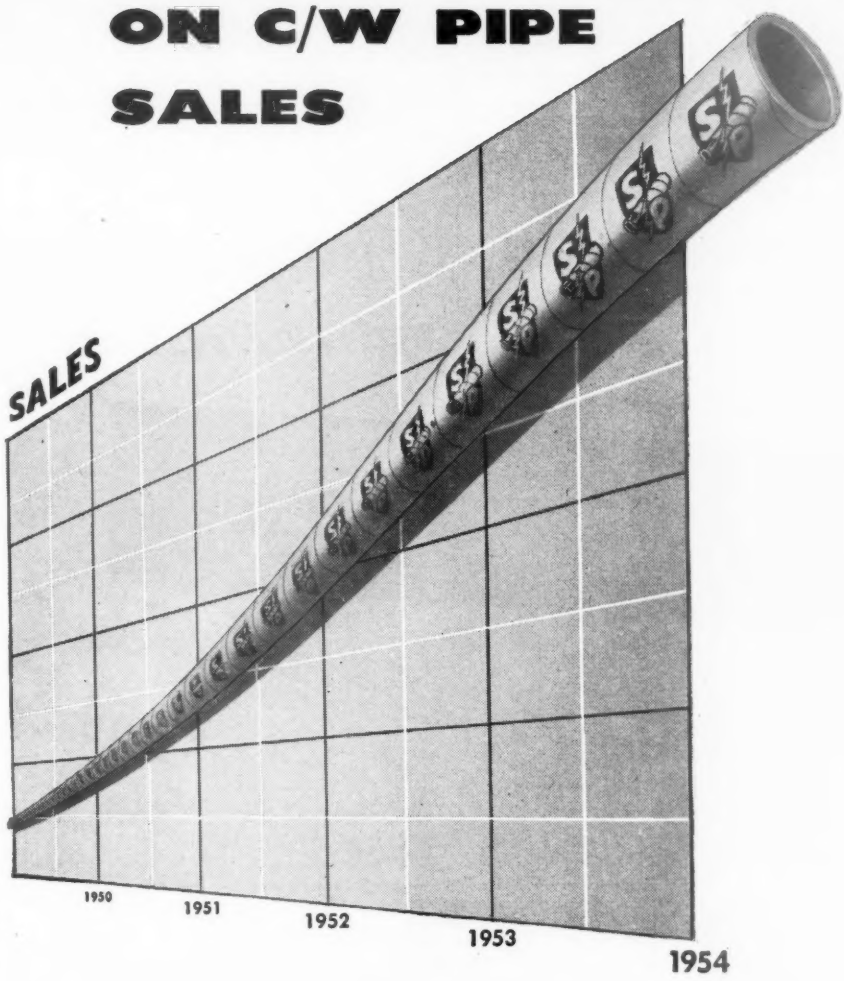
Approximately 60 per cent of the drilling was in red shale, in which progress was fast, and the remainder was either in rock of granitic origin or in quartzite, both of which were much harder than the shale. All told, the unit drilled 1075 holes, about 10,750 ft in the aggregate, or slightly more than 2 miles. The machine averaged around a hole per hour, or from 18 to 20 holes in two 10-hour daily shifts. This included all down time such as blasting periods, when the barge had to be moved downstream well out of range, and also days when no drilling was done. Actual drilling time was 30 to 35 minutes per hole.

Virtually all this work was done with 5 bits, 2 of 6-in. gage and 3 of 5½-in. Only 1 drill bar or rod was used during the weeks of work, and at the finish it was, to all appearances, as good as new. It is made of alloy steel, is 20 ft long and has an outside diameter of 3¾ in. and a central 2½-in. hole for the passage of air to blow out the hole.

Holes were loaded with 2 kinds of powder, both in 4½ by 22-in. cartridges weighing 16⅔ lb. In the bottom of each hole was placed a charge of "high-velocity" gelatin dynamite, which has great resistance to disintegration in water. On top of it were put either 2 or 3 cartridges of ordinary gelatin dynamite, followed by some sand stemming. Primacord, which was used for all firing, was connected to the water-resistant unit.

It is believed that in most instances the Primacord detonated the upper car-

THE RIGHT SLANT ON C/W PIPE SALES



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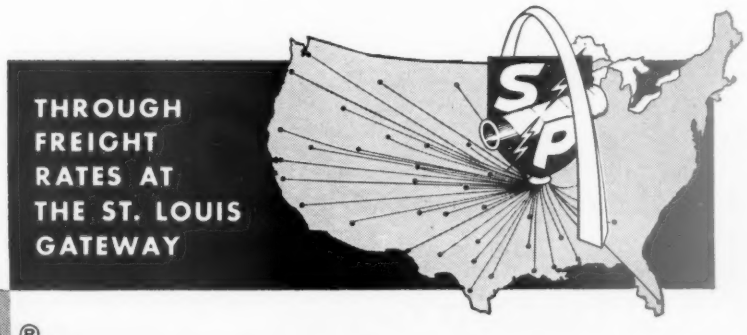

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tridges first, but there was always the assurance that if this failed to happen the bottom one would explode those above it. Holes were loaded soon after they were drilled. To the end of the short piece of Primacord extending from each of them was attached a small block of wood which floated in plain sight until the time came to make the connections for firing. Fifty or more holes were ordinarily blasted at a time, but one group of 650 was shot near the close of the work. Approximately 90,000 lb of explosives was consumed.

Blasting produced a trench with a V-shaped cross section up to 25 ft wide at the top. The broken rock that was not thrown aside was excavated with draglines equipped with buckets of ¾- and 1½-cu yd capacity. Each of these crawler-mounted machines built its own roadway in the trench as it moved along, first depositing rock behind it for that purpose and then, using that stretch as a base, removing material from in front of it and piling it alongside the trench.

Both the 24- and 16-in. seamless-steel pipe laid in the Susquehanna River section are of extra-heavy construction, having ½-in. walls. As received from the mill, the 24-in., 40-ft lengths weighed about 130 lb per linear ft. This was increased to more than 400 lb by concrete coating, reinforced with chicken wire. Prior to that, the pipe was given 2 coats of bitumastic enamel to protect it against corrosion. Sections that were to remain straight were delivered to the contractor already encased in concrete; those that had to conform to the contours of the terrain at the edge of the stream were bent in his yard on the east bank. The coated 24-in. line had a negative buoyancy of around 100 lb per running ft and the 16-in. about 60 lb, based on the specific gravity of water as 1.00.

The pipe entered the open trenches in the river from the eastern shore, additional sections being welded on as the strings extended farther into the water. Pulling power was supplied by a winch placed at convenient points. Lines were attached to deadmen and heavy pieces of equipment to give it the required stability to do the job. All welds were X-rayed with portable equipment. After the completion of a weld, the adjacent uncovered areas were doped with enamel and encased in a protective jacket of wooden strips wrapped with wire. Once the lines were in position, the trenches were backfilled by the draglines.

Acknowledgement

The photographs and material in this article were reprinted from *Compressed Air Magazine*, October, 1954, issue.

* * *

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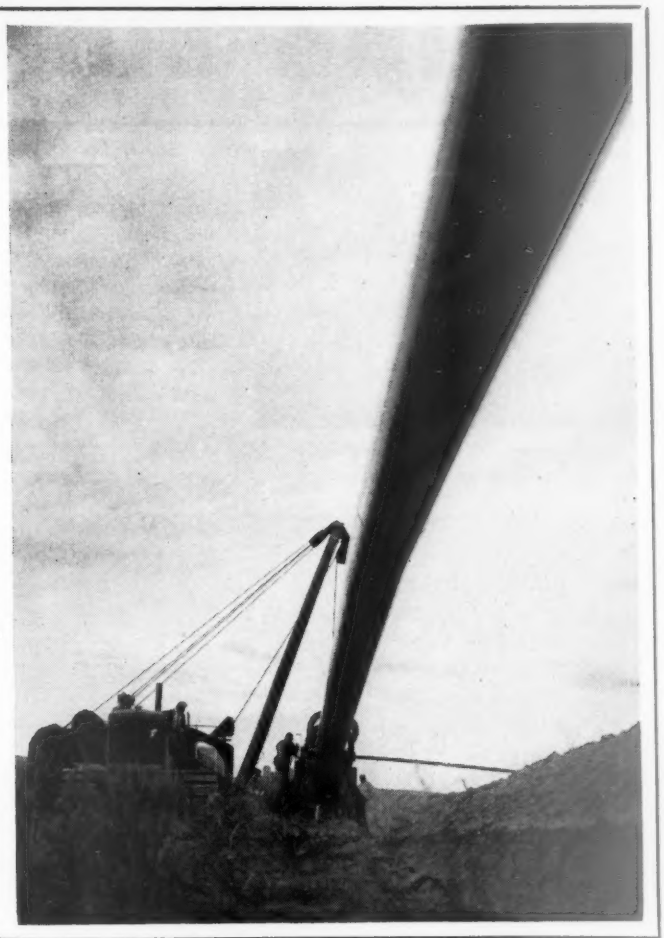

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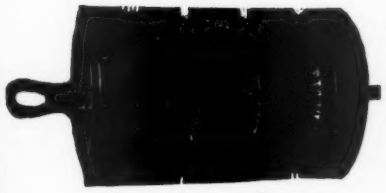

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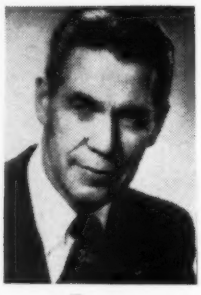
Pipe Line Projects

MacKimmie



Tanner

The 7th annual Pipe Lne Contractors Association convention, to be held in Los Angeles, January 16-19, will have a Canadian note. Featured speakers (left) include N. E. Tanner, president of Trans-Canada Pipe Lines, Ltd., and R. A. McKimmie, member of a Calgary, Alberta, law firm and specialist in gas legal matters.

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New Kansas Products Line Underway by Great Lakes

Construction of a 162-mile 10-in. pipe line from El Dorado, Kansas, to Kansas City is underway by the Great Lakes Pipe Line Company.

The new project will supplement present shipping facilities from El Dorado provided by an 8-in. line connecting to the Great Lakes system at Humboldt, Kansas, but will not parallel its route.

Because reserve capacity of the company's lines between Humboldt and Kansas City is not adequate for the indicated traffic volume from refineries at El Dorado and nearby locations, a separate line to Kansas City was required. Consequently, a direct course of shorter mileage was selected.

Initial daily capacity will be 36,000 bbl with power provided at El Dorado by a 1080-hp diesel-driven pumping unit.

When the line is completed, the company will discontinue the uneconomic operation of temporary secondary pumping stations on the 8-in. line at Eureka, Toronto, Selma and Bonita, all in Kansas. These stations had been added as an emergency method of furnishing increased capacity out of El Dorado until permanent needs could be determined.

Northeast Colorado Gas Line Proposed

Application has been made to the Colorado Public Utilities Commission by Natural Gas Producers, Inc., for authority to build 61 miles of pipe line at an estimated cost of $1,374,000.

The project would include 48 miles of 10-in. line linking northeast Colorado fields with Colorado Interstate Gas Company's main line from Hugoton field to Denver. Other lines would include 10 miles of 4-in. and 3 miles of 8-in.

Oklahoma Products Line Construction Underway

Construction of an 81-mile, 6-in. products pipe line that will link its Enid refinery to the Oklahoma City area market is underway by Champlin Refining Company, Enid, Oklahoma. River Construction Corporation, Fort Worth, Texas, is building the line.

Champlin announced a $4,000,000 expansion program at its Enid refinery last September, which will provide improved products for the new pipe line.

Alberta Crude Outlet

Application has been made by a group of companies operating in the Sturgeon Lake field area of northwestern Alberta to the conservation board of that province to build a pipe line outlet for their production.

The company formed to construct the line, Peace River Oil Pipe Line Company, Ltd., proposes a 16-in. trunk connecting the Sturgeon, South Sturgeon, and Little Smoky fields with a 106 mile, 12-in. line that would move crude south to the Edson, Alberta, pump station on the Trans Mountain Oil Pipe Line.

The 16-in. would have a maximum capacity of 139,000 bbl daily from the 3 fields. The 12-in. would have a 57,600 bbl maximum daily capacity.

Further plans would call for looping the 12-in. line and construction of a second 12-in. line to Edmonton as expansion becomes necessary. Backers of the Peace River Oil Pipe Line include Amerada, Gulf, Shell, Hudson's Bay, Imperial, and Union, all majors active around Sturgeon Lake.

New Buckeye Pipe Line Terminal Opened

Operation of a new terminal on the Buckeye Pipe Line at Dupont, Pennsylvania, has been initiated by Tide Water Associated Oil Company. Terminal will have storage facilities totalling 121,000 bbl and complete truck loading facilities. It is the second terminal completed this year on the Buckeye products line by Tide Water. First in opertion was at Macungie, Pennsylvania.

Gas Sales Predicted Third Higher by 1957

Sales of gas by utilities and pipe lines in 1957 will aggregate 74.3 billion therms, an increase of 31.5 per cent over actual sales of 56.5 billion therms in 1953, according to a report on gas requirements and supplies just published by the American Gas Association. Supplies of gas from existing and planned facilities to meet these increased requirements will total 81.6 billion therms, an advance of 20.7 per cent over total supply of 67.6 billion therms available last year.

To meet increased demands for service, the gas industry will require 4.6 million tons of steel pipe during the 1954-1957 period inclusive. Of this amount 2.9 million tons will be in the form of 16-in. diameter and over, primarily used for gas transmission lines. An additional 134,000 tons of steel in other forms and 446,000 tons of cast iron will be required by the industry in the 1954-1957 period.

An estimated $114,000,000 will be expended during the next 4 years on underground storage projects. Anticipated withdrawals during 1957 will aggregate 4.9 billion therms while on the 1957-58 peak day the expected underground storage withdrawals of 102 million therms will represent one-fourth of the total available supply of gas from all sources for the entire industry.

The greatest relative post-war increases in demand and in customer acceptance of gas for gas househeating have occurred in northern areas. This reflects the tremendous pipe line expansion program making more gas available to the metropolitan centers of the North. Also reflected are the high heating saturation that has historically existed in the southern part of the country, and greater consumption requirements per customer in northern localities.

Data shown in the AGA report provides comprehensive forecasts of national and regional statistics on an annual basis through 1957 and on the peak day through the 1957-58 heating season. Data shown relate to the entire industry and are based on replies to questionnaires from 159 gas companies, representing 87 per cent of industry sales.

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Projects

Alberta Gas Trunkline Project Permit Given

Permission to build a 300-mile, $38,000,000 gas gathering system has given Alberta Gas Trunk Line by the Alberta government. The permit will allow the firm to build the vast trunk system in time to meet requirements of the Trans-Canada gas pipe line.

The company will also supplement its permit by conducting a study on the cost of constructing feeder lines for the purpose of arriving at estimated tariffs on moving gas from the field to the Saskatchewan border where Trans-Canada will take gas.

A committee consisting of representatives of the three concerned groups—Trans-Canada, the trunk line, and producers—has been set up to insure continuing and active liaison.

The feeder line costs and tariffs study is expected to facilitate the signing of gas sale contracts between producers and Trans-Canada.

Smiley Field Line In Canada Operation Ready

A short crude oil pipe line connecting the Smiley oil field in central western Saskatchewan with the Interprovincial Pipe Line at its Kerrobert pumping station is scheduled to be in operation early in January.

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R. E. Ashley, Carter engineer, right, uses reservoir model to demonstrate how Carter is using flood to recover an additional 100 million barrels of oil at Loudon, Illinois.

WALLACE PRATT, world famous geologist, said: the place to find oil "is in our own heads."

Carter production people, engineers and geologists proved how right he was in their work at Loudon. And they did it almost without leaving their desks.

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Water flooding would do it.

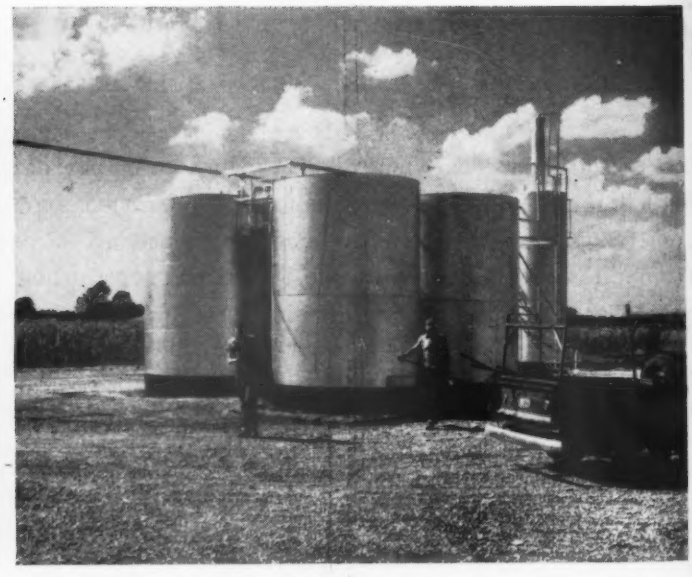
Speaking to a group of 50 Illinois and New York City newspapermen, radio people and state officials who toured the field late in August, John Sprague, Eastern Division manager, forecast this massive increase in oil re-

†Reprinted from The Link, published by The Carter Oil Company, issue of September-October, 1954.

Another 100 Million Barrels

Vast Carter water flood project rejuvenates old wells in Illinois field

L. Q. Loftin, left; W. F. Lytle and Walter Frisby test gas accumulator before installing it on water injection pump.



Roustabouts Robert Sprehe, left, and Harry Beccue put finishing touches to gravel mat around tanks on Bennie Shaw lease.

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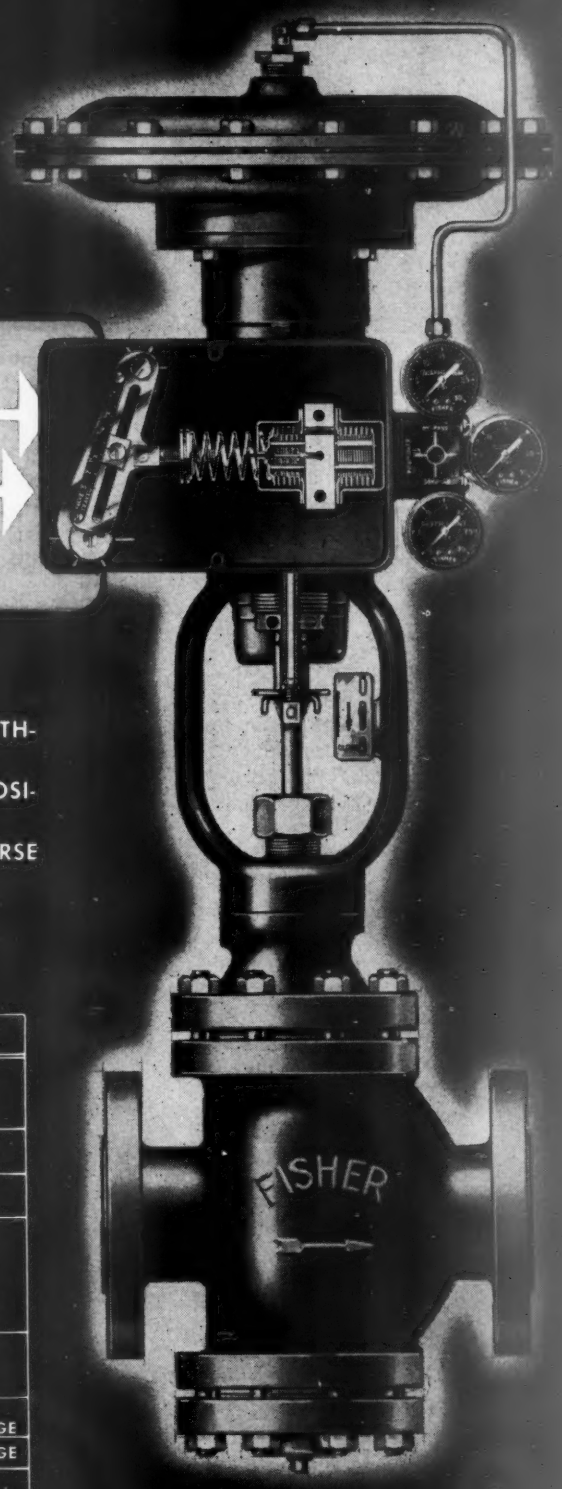

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	2" TRAVEL		0.015" AVE.
SPEED TIME IN SECONDS FOR FULL TRAVEL	SIZE	TRAVEL	
	DD	¾"	1.2 — 1.2 SEC.
	FF	1½"	4.2 TO 4.8 SEC.
	GG	2"	7.2 SPC TO 9.6 SEC.
	HH	2"	10.5 TO 12.6 SEC.
LAG ERROR IN POSITION AT 9 LBS. CONTROLLER PRESSURE	½" TRAVEL		0.0006" AVE.
	2" TRAVEL		0.001" AVE.
EFFECT OF VARIATIONS IN AIR SUPPLY PRESSURE	½" TRAVEL		0.1 LB. PER 5 LB. CHANGE
	2" TRAVEL		0.1 LB. PER 5 LB. CHANGE
CHARACTERISTICS CONTROLLED P VS DIAPHRAGM P			LINEAR
COMMENTS			STABLE ADJUSTMENTS ALL EASY AND SIMPLE
AIR CONSUMPTION NORMAL 9 LBS. DIAPHRAGM PRESSURE			15.0 CU FT/HR

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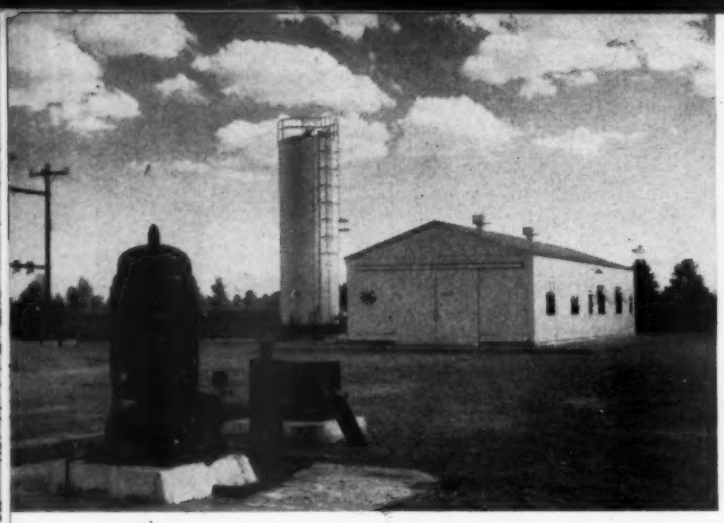

Source well in foreground, storage tank and pump house are typical of our 10 water flood plants in the Loudon field.

Interior of spotless Bennie Shaw pump house where Walter Frisby, meter man, adjusts electrically-driven injection pump.

covery at Loudon through use of secondary recovery methods.

Primary recovery methods generally recover not more than 25 per cent of the oil in Illinois fields. Loudon is no exception.

From a peak of 48,000 barrels of oil a day in 1940, Carter's production at Loudon gradually declined to 12,000 barrels a day by 1950. Only by gas repressuring and other steps taken to bolster production had we been able to keep it even that high. Production would continue to dwindle. Were we to stop now knowing that three-fourths of the oil was still underground? Not by a long shot.

So, beginning in 1950 Carter drilled three water injection wells to the producing formation. We started a small pilot flood on 90 acres. For more than a year nothing happened.

And this was good. Our engineers considered it a very hopeful sign because it meant the water was not bypassing dormant oil in the formation. It indicated that water was pushing and shoving oil ahead of it to the producing wells.

Then, late in 1951, production at nearby wells spurted. By early 1952 wells which had been producing three to four barrels of oil began pumping 100 or more after the water flood "kick"!

Confident now that most of the field would respond to water flooding, Carter swung into action on its broad program to flood the field.

"Increased oil production due to water flooding already amounts to 7,500 barrels daily," W. F. Eiting, Division production manager, told the visiting newsmen. "The total cumulative gain since water flooding began in 1950 is an impressive 2,600,000 barrels of oil! Without water flooding that oil never would have gotten to the surface."

Six thousand, seven hundred acres are now under flood. In acres flooded —when complete—Loudon will be one of the largest single fields under flood in the world.

Eventually the flood will cover virtually all of 22,000 acres in the field which rambles over the Illinois hills for roughly 15 miles and averages 4 miles in width.

"Our basic problem at Loudon is to pump enough water underground to fill all the empty or void space remaining in the formation," Eiting said. "It is a task of tremendous magnitude." He pointed out that 160 millon barrels of oil have been removed from this formation since the field's discovery in 1937. That's a lot of empty space.

To get water to fill the void space

Franklin Bernahl, roustabout, checks a water source well.

James Broaddus, water flood pumper, at an injection well.

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LOW PRESSURE DROP
PLENUM CHAMBERS FOR HAZARDOUS AREAS
EXPLOSION RESISTANT
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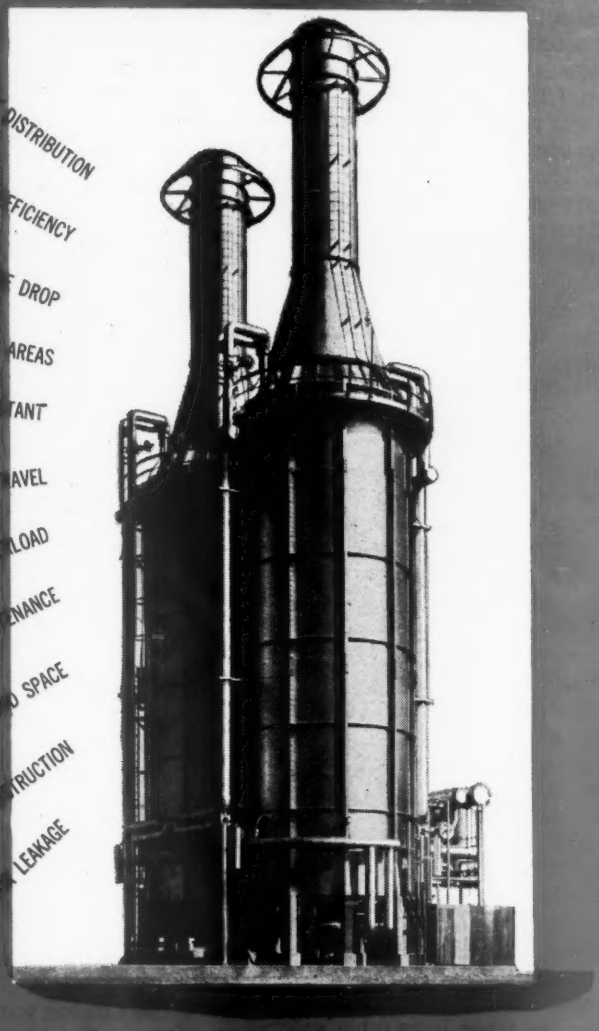
EXCESS DRAFT FOR HIGH OVERLOAD
LOW MAINTENANCE
MINIMUM GROUND SPACE
SIMPLICITY OF DESIGN AND CONSTRUCTION
ZERO AIR LEAKAGE



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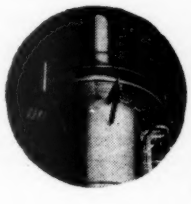

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left by the withdrawal of this 160 million barrels of oil, Carter is drilling water source wells to the Tar Springs sandstone, a salt-water saturated formation 1,100 feet below the surface.

All this water is filtered and injected underground into the Chester sandstones. These formations, like gigantic rock sponges, are filled with microscopic pores or void spaces. Once those void spaces left by the removal of produced oil are filled with water—and still more water is coming in—something has to give. Thus the water begins to push the oil through the rock to the well bores.

"Carter already has injected more than 22,000,000 barrels of water underground," Eiting told the newsmen. Daily average water injection rate now is 69,000 barrels a day. Later our engineers expect to inject as much as 125,000 barrels of water per day when all of the floodable acreage is included. It would take 525 railroad tank cars to haul one day's supply.

Already Carter has completed or nearing completion ten water injection plants, each one consisting of source wells, pumps, prime movers, filters and storage tanks. All plants are interconnected. Mechanical breakdowns at one plant then will not halt injection in the trouble area.

Operation and maintenance of the plants is handled by experienced Carter men from our gasoline plants in the field.

No water from streams or lakes and no industrial water from other sources is being injected at Loudon. The salt-laden water from the Tar Springs formation gets special handling to adapt it even for our use. It is injected through a closed system which excludes air, reducing corrosion of pipes and pumps.

Already some of this injected water is being lifted back to the surface with the oil. Separated from the oil, the water then is refiltered and re-injected into the producing formations. Again and again this water will make the trip underground. Engineers call it recycling. Near the end of the operation, 15 or more years hence, engineers predict 90 to 95 per cent of the water being used will have made numerous trips underground.

And the water is doing its work well.

Wells Show Increase

To date 501 wells are showing increased oil production from water flooding. Carter has converted 168 old wells to water input wells. It has drilled 32 new wells.

Where old wells are converted to water input service, a small spudder rig is moved in to clean up the well so it will take more water.

Five such spudder rigs now are operating in the field converting wells to water injection service or completing new water wells. Sometimes, depending on sand conditions, two formations can be opened to water injection in a single well.

Cooperative Project

And such technical problems weren't the only headaches. The Loudon water flood is a "cooperative" project—not a unit operation. A unit could be operated as one big field.

Before starting the water flood project on a large scale Carter representatives contacted 1,842 individual royalty owners representing 4,169 separate royalty interest. One farm alone had 126 different royalty owners. Owners of royalty at Loudon lived everywhere in the United States and Canada. Some were even in Europe.

Steve Huston, Division land man, assigned Robert J. Leman, office land man as the "pusher" for people we hired to contact royalty owners. Leman was aided by E. L. Stewart, Jr., and later by Hunter L. Martin, Jr. Under Leman's direction our representatives drove a grueling 120,000 miles in a little over three months to secure "consents" from royalty owners.

When these "consents" were filed with the circuit clerk of Fayette County, they filled six and one-half volumes of 650 pages each. The recording fee—$3,064—was the largest single recording fee ever paid Fayette County.

The Loudon water flood puts money in the pockets of royalty owners. Some leases have experienced ten-fold increases in production from water flooding. An average well which had declined to two or three barrels of oil per day now pumps its allowable of 75 barrels.

One royalty owner, in the initial flood area, getting a substantially increased check for the first time, wrote Carter to ask if a mistake hadn't been made.

There was no mistake!

Other royalty owners got bigger checks as the flood expanded.

All this work meant too, that sound secondary recovery methods at Loudon added 100 million barrels of oil reserves in the state of Illinois. Without this conservation step the oil would have lain dormant in the earth—of no value to anyone.

All that "head" work and physical labor achieved the equivalent to discovering a great and entirely new oil field containing 100 million barrels.

Measure that by this rule of thumb in the oil industry. Only one wildcat well out of every 967 drilled in the U.S. ever finds a field with recoverable reserves of even 50 million barrels.

* * *

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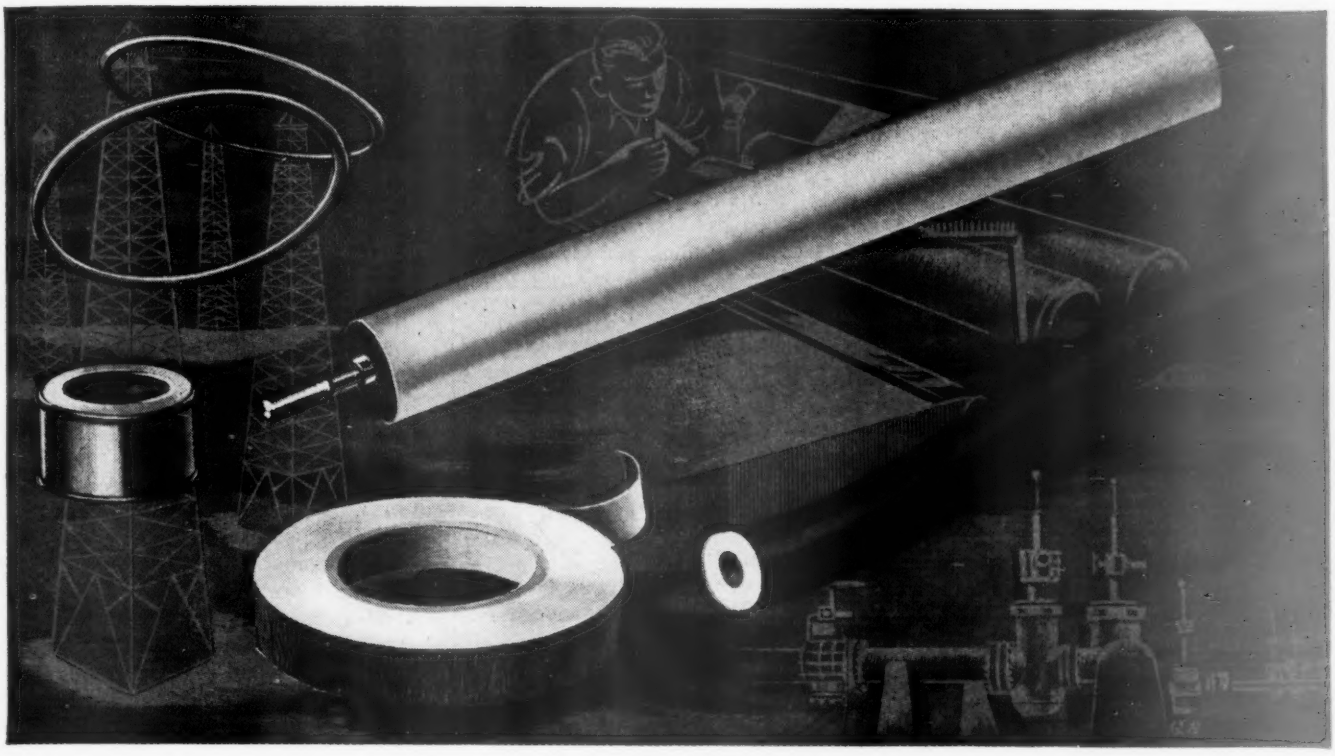
Sun Builds Lab

Sun Oil Company has begun construction of its $400,000 production research and development laboratory north of Dallas, Texas. Structures include a single-story "E"-shaped lab and a service building. Completion is slated July 1, 1955.

XUM

Announcing... PARACRIL D



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When all production factors are under control one still remains — the willingness to work — and it often determines the profit margin.

MORALE and Productivity

Dick Carlson

THE greatest of all arts is the ability to create circumstances which cause people to want to produce to the maximum of their capacity in the attainment of common objectives, not because they have to, but because they want to.

Productivity is dependent upon a variety of conditions. It involves the product, plant design, flow of work, facilities and equipment, production know-how, methods, procedures, and many other engineering factors. In addition to these engineering factors productivity is also dependent upon morale, a willingness to work, and job satisfaction on the part of employees.

Attitude of Mind

Morale is an attitude of mind. It is the unconscious fragile spirit that permeates the entire organization. It takes a long time to develop it. It is fluid and unstable. It is never permanently established, and it must not be taken for granted.

Top management must accept final responsibility for the morale and productivity of the total work force; for employee attitudes, and their willingness to produce, for attaining maximum production with a minimum of stress, strain, and friction; and for teamwork and loyalty of the work force.

In order to maintain morale and productivity, it is essential that adequate management controls be established and maintained which will assist the president and his board of directors to: (1) Project desired results accurately; (2) identify and forecast major trends; (3) determine needs for changes; and (4) to detect problems in time to take corrective action before they become critical.

What can top management do to create the climate which causes high morale and productivity? Five steps which will improve morale are:

1. Develop and publish objectives and policies. This takes courage and skill, but whenever men place greater emphasis upon security or the status quo than they do upon opportunity, initiative withers and dies.

2. Create relationships and conditions. All executives and supervisors must have pride in their organizations, pride in their own jobs, and pride in the accomplishments of their subordinates. Experience proves that the performance of total work force is directly related to quality of supervision.

3. Develop acceptance. Build up in the minds of first and second line supervision, as well as the top executives, an understanding and acceptance of what the company is attempting to accomplish—a deep conviction about the organization's purposes.

4. Conduct well-planned and effective meetings regularly (a) at least once a year—all employees; (b) three or four times a year—all supervisory personnel; (c) once a month—all key management personnel; and (d) weekly—top management conferences, as required. It's what happens in the executive sessions of management, when the doors are closed and the chips are down, that makes for real "morale" in the organization.

5. Issue well-designed and interesting publications: (a) company paper —weekly or monthly; (b) management reports to employees—annually or quarterly; (c) reports to owners, members, stockholders, or policyholders — annually; (d) periodicals and special reports as required; (e) handbooks, standard practice instructions; (f) organization manuals, at appropriate levels; and (g) continuous training materials.

Some of the strongest incentives that can be provided by management in the development of employee morale include recognition of individual abilities and interests; opportunity insofar as practicable, proportionate to performance; rewards (non-financial as well as financial) commensurate with performance.

We can see how some of these viewpoints and principles were put to work by the management of the Farm Bureau Insurance Companies. A preliminary study emphasized the fact that their organization structure had, through the years, like Topsy, "jes' growed." Departments had developed around strong individuals, rather than around major functions. As in other organizations, many problems could be traced in part to inadequate organization structure.

Question and Answer

As soon as the management of these companies agreed that a revised organization structure was imperative, the question was asked: "Reorganization along what lines?" The answer was, "A structure well-designed to accomplish most effectively the overall objectives of the organization."

Without a definite written statement of company objectives, it is difficult to design a sound organization

The Author

Dick Carlson has participated as a consultant in studies of top-management problems in a wide variety of industries such as railroads, mining, finance, insurance and wholesale distribution; the manufacture of heavy machinery, motors, jewelry, pullman cars, cosmetics, paper, glass and building materials. He joined Rogers, Slade & Hill, New York, in 1945; partner since 1947; consultant for Farm Bureau Insurance Companies since 1948. Served in Washington as Director of Personnel for the FCA, CAA, and FCC, 1935-45. Management Consultant, Department of Defense, 1949-50; past president of the Society for Personnel Administration.

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structure or to develop criteria for appraising the effectiveness of management, except by opinion, guesswork, or individual judgment.

Whenever a company undertakes a reorganization program, it takes courage to let the chips fall where they may. Whenever the careers and the status of top executives are affected in a reorganization program, there is always a grave danger that fundamental principles and major issues will be obscured by self-interest. Unless management has the will and the courage to be completely objective, little improvement can be made.

Good organization, however, is not a cure-all. If any executives are weak, no amount of tinkering with the organization structure is going to solve that problem. Imaginative and capable management is a constant need that doesn't end with the adoption of an organization structure.

The Next Step

After the revised plan of organization was established, the next step was the development and adoption of an executive salary program. This included the design and installation of an executive position classification plan for the grading of more than 700 supervisory and management positions; the establishment of equitable salary ranges for each grade; the classification of all positions affected from the first-line supervisors to and including the president, and the adoption of a systematic program for appraising executive performance, together with a well-organized plan for approving salary increases.

The companies' next major problem was "growing pains." Based upon the successful experience of two pilot programs, the decision was made to decentralize all operations. Since that time several regional offices have been moved to regional locations, and all the companies' operations have been completely decentralized into geographic units.

Every one of the moves has gone off like clockwork. Details have been thoroughly worked out in advance by those to be affected. Each of the regional offices has gone through the same kind of staging treatment.

A definite plan has been developed and adopted to assure adequate coordination of all phases of management including line and staff executives, home office, and regional operations.

Concurrently with the decentralization, the Farm Bureau management faced the problem of establishing management controls and reports which would reflect current adherence to established objectives, budgets, and programs for the organization as a whole, the home office staff, and each of the regional offices. This has been accomplished through: 1. Organization manuals, which outline in writing descriptions of all management jobs, as well as the objectives, functions, responsibilities, and criteria for measuring the performance of every major home office and department within the companies. 2. President's report to the board, which summarizes monthly and quarterly the company's accomplishments of total end results in conformity with over-all objectives and policies as previously approved by the board. 3. Management control reports, which reveal currently the basic information necessary to assure adherence to establish objectives and standards by each major department.

The fundamental improvements in operation reveal in part the results of the long-range management improvement program which created the circumstances necessary in order to change the previous trends of decreasing productivity and increasing costs.

Remedial Action

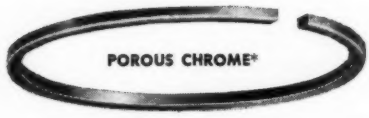
I believe that what has been done by these companies to improve morale and productivity can be done by almost any organization, to the extent that its management will analyze the causes of any unsatisfactory trends in its operations and then apply effective remedial action. * * *

FINANCIAL REPORTS FOR FIRST NINE MONTHS OF 1954†

Name of company	Gross income 9 mo., 1954 $000	Gross income 1953 $000	Per cent change from 1953	Net income 9 mo., 1954 $000	Net income 9 mo., 1953 $000	Per cent change from 1953	Per common share net income 1954	Per common share net income 1953	Price per share Sept. 1954	Price per share Dec. 1953
Amerada	61,617	63,543	− 3	11,657	12,962	−10	3.70	4.11	181½	165
Anderson-Prichard	41,399	38,983	+ 6	2,535	3,368	−25	3.12	4.14	44½	43⅛
Argo Oil	7,808	7,001	+12	3,310	3,333	− 1	1.66	1.67	24	18
Ashland O & R	172,503	177,884	− 3	5,124	7,736	−34	.72	1.21	12¾	11¾
Atlantic	433,395	447,215	− 3	26,401	33,062	−20	2 84	3.58	34¾	28
Bishop	1,361	1,332	+ 2	160	178	−10	.43	.48	11¾	11
Cities Service	619,459	644,727	− 4	30,911	37,715	−18	7.95	9.70	107¼	78
Continental	373,502	358,698	+ 4	31,337	31,163	+ 1	3.22	3.20	71	52
Cosden Pet	35,722	34,068	+ 5	2,423	2,179	+11	2.34	2.69	19¾	15⅞
Deep Rock[5]	29,962	31,099	−.4	2,416[5]	1,024	+136	5.24	2.28	46½	35⅛
Derby Oil*	17,312	16,424	+ 5	745	961	−22	1.60	2.07	24¾	16⅛
General American[1]	13,922	13,667	+ 2	6,573	5,388	+22	5.49	4.71	48¼	40½
Gulf Oil	.....	1,205,000	....	116,359	116,828	± 0	4.74	4.76	61½	46¼
Hancock	32,618[3]	38,153[3]	−15	5,106	12,029	−58	1.62	3.86	28¼	20
Honolulu	22,837	21,944	+ 4	8,129	7,712	+ 5	4.33	4.11	71¼	57
Houston Oil	24,029	24,010	± 0	4,308	5,002	−14	3.23	3.77	77¾	66¾
Hugoton Production	3,133	2,982	+ 5	1,485	1,244	+19	1.75	1.46	45½	40
Husky[1]	13,741	9,057	+52	1,004	587	+71	.34	.17	7	6
Kerr-McGee[1]	32,371	32,339	± 0	2,360	2,669	−12	1.86	2.12	41¼	41
Lion Oil	73,552	68,158	+ 8	7,588	7,450	+ 2	2.45	2.41	41⅞	29⅞
La. Land & Exp	18,778	16,764	+12	10,579	8,017	+32	3.55	2.69	74¾	51⅜
Maracaibo	1,500	1,525	− 2	341	324	+ 5	.69	.65	9⅛	7
Mid-Continent Pet	122,276	128,004	− 4	9,795	10,626	− 8	5.25	5.72	93½	66
Middle States	8,310	8,571	− 3	1,662	1,901	−13	.72	82	12¾	12⅜
Monterey Oil	5,189	5,288	− 2	553	1,912	−71	.43	1.72	34⅝	33⅝
Ohio Oil	187,218	181,267	+ 3	28,281	33,025	−14	4.31	5.03	65⅛	53¾
Pacific Western	10,668	8,796	+21	5,276	8,969	−41	.93	1.64	33¼	31⅛
Panhandle Oil	9,802	9,682	+ 1	658	664	− 1	.41	.42	7⅛	6
Phillips Pet	586,779	565,702	+ 4	55,615	55,458	± 0	3.80	3.80	62⅜	53½
Plymouth Oil	68,623	73,442	− 7	4,930	6,744	−27	2.05	2.81	28	23⅝
Pure Oil	.....	.....	....	20,829	18,518	+12	4.71	4.14	62½	46⅜
Quaker State	33,682	37,310	−10	1,480	1,534	− 4	1.79	1.66	25⅛	21⅜
Richfield	159,794	149,190	+ 7	18,278	19,359	− 6	4.57	4.84	57⅜	48
Seaboard	29,078	28,803	+ 1	5,346	5,214	+ 3	1.46	1.43	37½	29½[4]
Shamrock Oil & Gas	28,305	25,049	+13	5,473	4,184	+31	3.65	2.82	49⅝	40¼
Shell Oil	975,711	933,476	+ 5	89,545	81,481	+10	3.26	2.97	56	38½[4]
Signal	.....	.....	....	6,709	6,327	+ 6	1.88	1.78	26¼	19¾
Sinclair	741,539	683,478	+ 8	52,896	47,506	+11	4.29	3.87	46⅛	31¾
Skelly	156,312	164,564	− 5	20,933	22,600	− 7	3.64	3.93	45½	35½
Socony-Vacuum	1,185,400	1,189,900	± 0	128,000	133,000	− 4	3.65	3.80	48¼	35½
Standard California	904,366	859,382	+ 5	154,921	140,217	+10	5.15	4.66	75¾	52⅞
Standard Indiana	1,240,428	1,284,546	− 3	81,444	88,634	− 8	5.24	5.76	92⅞	68½
Standard Jersey	4,235,000	4,156,000	+ 2	438,000	432,000	+ 1	7.23	7.13	100	72
Standard Ohio	236,855	252,157	− 6	12,385	14,198	−13	2.93	3.38	41⅜	32
Sun Oil[3]	328,343	322,115	+ 2	20,407	21,659	− 6	2.64	3.03	78½	69¾
Sunray Oil	94,200	105,445	−11	15,900	18,900	−16	1.51	1.84	19⅜	16⅛
Superior[1]	77,421	73,136	+ 6	10,360	12,000	−14	24.53	28.36	725	650
Texas Company	1,228,076	1,193,823	+ 3	151,880	133,353	+14	5.53	4.85	79	57⅝
Texas Gulf Prod	9,710	8,218	+18	3,813	2,912	+31	3.12	2.63	89½	39
Texas Pacific C & O	16,201	16,039	+ 1	5,697	5,684	± 0	3.21	3.21	45	34¾
Tide Water Associated	338,289	349,232	− 3	26,967	26,915	± 0	2.01	2.00	24½	20½
Toklan Royalty	941	868	+ 8	238	169	+41	.27	.20	4⅛	4⅛
Union Oil of Calif	266,038	238,207	+12	27,151	28,007	− 3	3.98	4.11	49¼	38½
Union Sulphur & Oil	13,921	15,333	− 9	936	1,306	−28[6]	1.05	1.95	44	37¾
Universal Consolidated	2,949	4,117	−28	1,201	1,803	−33	1.99	3.09	63	58
Warren Pet	89,680	90,753	− 1	6,387	7,602	−16	3.76	4.47	38⅜	30⅛
Wilcox Oil	7,496	6,636	+13	437	708	−38	1.56	2.52	22½	21¼
Woodley Pet	2,405	2,144	+12	482	437	+10	.58	.59	40	33

†Revised and corrected list.
*Now merged with Colorado Oil and Gas Corporation.
[1]Period of 1 year ending June 30.
[2]6-month period ending June 30, 1954.
[3]Dividends from affiliates were $3,133,000 in 1954; $10,229,000 in 1953.
[4]Adjusted.
[5]Includes sales of oil properties.
[6]In 1953 earned $201,172 in steamship operations; lost $32,991 in 1954.

XUM



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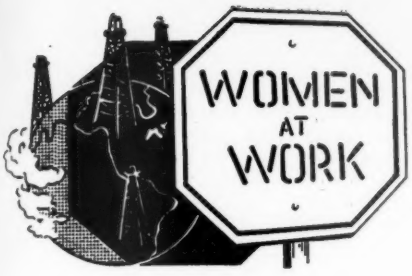

Geological Draftsman

Olivia Whitehurst of Shreveport, Louisiana, is one of the few women geological draftsmen in the country. Trained and experienced as a high school history teacher she had a natural talent in art and her brother, chief draftsman for an oil company, encouraged this talent.

So when her husband was serving with the Coast Guard during World War II, Olivia enrolled in a night school engineering drawing course, finished it, and took a job as draftsman with a firm of electrical engineers.

In 1950, backed by college geology training—she holds a degree from Centenary College, Shreveport — and by art training at Southwestern Institute of Art, Mrs. Whitehurst joined Texas Eastern Transmission Corporation as a geological draftsman. After Texas Eastern Production Corporation was organized she was transferred to that organization in the same capacity. She is quite at home making maps of various oil and gas fields and prospective productive areas, laying out stratigraphic sections, and keeping regional maps up to date with the latest well and lease data.

Olivia spends most of her spare time with her favorite avocation — nine-year-old Sherry Whitehurst. She occasionally finds time for her hobby of photograph painting, and recently she completed a project that she considers the best-loved drawing project of her life—that of designing the dream home where she and her family now live.

An authority on oil maps.

Holds a Top Job in Houston

Dorothy Harbison, fresh out of high school and 16 years old, had no idea how big a job she'd landed when she went to work for Dr. John D. Todd, Houston geologist, in January, 1945. Her employer sometimes tells it that he "took her to raise," but Dorothy's straight A record, her valedictory honors, and her bubbling-over personality weighed heavily in his decision to hire her. Ten years later, Dorothy and Dr. Todd are both glad of their choices.

Officially Dorothy is secretary to Dr. Todd, but her duties cover a multitude of things — among them setting up all lease files, approving payments of drafts, sending instruments for record, paying rentals, ordering title certificates and doing preliminary curative work before the certificates are turned over to an attorney. With mineral and royalty interests in Texas, Louisiana, Oklahoma, Alabama, Florida, Mississippi, and New Mexico, Dorothy is hardpressed to find time to keep abreast of their interests and to keep her employer posted on developments around his properties. She also handles the correspondence and does the accounting for the geological office.

Ten years with one company.

Dr. Todd owns Cambe Log Library, a company engaged in the reproduction and distribution of electrical logs on the Texas and Louisiana Gulf Coasts. The company maintains separate offices and employs 18 people. Dorothy assists in the management of Cambe, interviews all new personnel, makes recommendations for promotions, supervises bookkeeping department, manages the geological book department.

Off-duty, Dorothy devotes her time to Roy Harbison, Jr., her husband — also an oil careerist, with Stanolind — to their new home in Oak Forest, Houston, gardening and taking home movies. For the first two years after she went to work she studied at the University of Houston Downtown School. In addition, she's had courses in personnel management, abstract and oil and gas law.

CORRECTION—Dr. Marjorie Vold, December Women at Work, is a research associate with the University of California. Dr. Robert Vold, her husband, has never been employed with Union Oil Company, as implied in the article.

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PERSONALS

George L. Bonar, assistant to the president of The Texas Company, has been named assistant to the chairman of the board, and **Hanson D. Teeters,** executive assistant in the finance and economics department, has been made assistant to vice president. Bonar became associated with Texaco's refining department at Tulsa, Oklahoma, in 1928. He served in various capacities in Houston and New York City, becoming assistant to the vice president in Houston, Texas, in 1944. Teeters began his service with Texaco in 1928 as credit manager in Los Angeles, California, and later became general credit manager in the treasury department, New York City. He was named executive assistant in 1952.

Russell J. Cooper has been appointed manager of The Texas Company's newly-established salary standards division. **Joseph J. Albaum** has been named assistant manager. Cooper joined Texaco in 1917 as an accounting clerk in the export department. He was named assistant manager of the personnel division in 1949. Albaum began his service with The Texas Company as a voucher clerk in the export department in 1932.

Texas Company, has announced the election of **Robert Fisher** as financial vice president and **Stanley T. Crossland** as vice president and treasurer, both effective January 1, 1955. Fisher, treasurer of the company since 1949, succeeded **L. H. Lindeman.**

Fisher entered the employ of The Texas Company in 1910. His positions with the company include those of assistant cashier, cashier, and assistant treasurer. In 1949, he was elected treasurer of the Company.

Crossland went to Texaco with a broad background of financial and banking experience. Following the creation of the Reconstruction Finance Corporation, he had served in various capacities, the principal one being executive vice president of the Rubber Reserve Company. He joined Ethyl Corporation in 1945, serving until his election as an officer of The Texas Company.

The company also has announced the appointment of **Robert G. Rankin,** assistant comptroller, to the newly-created position of director of the budget. Rankin became associated with the Indian Refining Company at Lawrenceville, Illinois, in 1925. This company later became affiliated with The Texas Company. He became assistant comptroller in 1944.

William R. Love, special auditor in the comptroller's department and assistant to Rankin, will succeed the latter as assistant comptroller. He joined Texaco in 1947 as a traveling auditor.

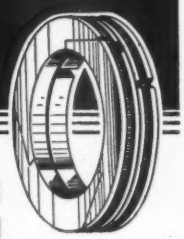
H. E. Snow, who was one of the three-man Consortium delegation which negotiated the oil agreement with Iran, has resigned from the board of Anglo-Iranian Oil Company, Ltd., on taking up the appointment of general manager of Iranian Oil Participants, Limited. Iranian Oil Participants, Limited, incorporated in London where it has its headquarters, is the holding company for Iranian Oil Exploration and Producing Company and Iranian Oil Refining Company, the two companies formed to operate the Iranian oil industry under the recent agreement between the Iranian government and eight oil companies.

Mrs. Martha Binford, executive secretary with Seaboard Oil Company, Dallas, Texas, has been awarded an OIIC Gold Award for "outstanding" work in the Gulf-Southwest information and service program. She received the award, the first ever given to a woman, for guiding the Texas women's activities in the American Petroleum Institute's public relations program. The presentation was made by **Roy J. Diwoky,** executive vice president of Pan-American Southern Corporation, New Orleans, La., at the Gulf Southwest Oil Industry Information Committee meeting.

Wiley B. Cotten, Jr., manager of the public relations department, Esso Standard Oil Company, Baton Rouge, Louisiana, has been elected by the board of directors of the Public Relations Society of America to a three-year term as a director representing the society's southern district. Cotten has spent all of his 38 years in business with Esso, starting as a stenographer in the purchasing department at the Baton Rouge refinery in 1916. Since then he has served in various administrative and executive capacities with the company in Baton Rouge, New York, and New Orleans. He was appointed to his present position at Baton Rouge in 1944.

M. J. Casey has joined the general manager's staff of the new supply transportation department of Standard Oil Company of Indiana. He will be supervisor-administrative, transferring from assistant supervisor of labor relations in the general office industrial relations department. Casey joined Standard in 1932 as an accounting clerk in the Indianapolis, Indiana, sales division.

MAXIMUM CHOICE OF MATERIALS when you use these METALLIC PACKINGS



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Personals

George C. Caine

George C. Caine, has been relieved of his duties as general superintendent of Tide Water Associated Oil Company's Bayonne, New Jersey, refinery, to direct and coordinate all activities relating to the planning, design and development of the company's new refinery, scheduled to be built somewhere along the eastern seaboard. Caine joined Tide Water Associated in March, 1926, as an engineer in the development department at Bayonne. Caine was named assistant general superintendent of the refinery in 1938, and general superintendent, in 1943.

Tide Water Associated Oil Company has appointed **Charles N. Pollak** as public relations manager, a newly created position. He will have headquarters in San Francisco, California.

Miss Marceline Marquis has been appointed supervisor of women's activities for the Oil Industry Information Committee of the American Petroleum Institute. She succeeds Miss **C. A. Moon.** Prior to her affiliation with the industrywide public relations program, Miss Marquis had been with Ethyl Corporation for 10 years as editor of its employee magazine. In her new assignment, Miss Marquis will prepare the many special materials which will bring the story of oil to women's audiences and groups all over the country. She is a graduate of the University of Tulsa and also attended Baylor University.

Annual Index

for

1954

The

Petroleum Engineer

The editorial index of all articles published in *The Petroleum Engineer* during 1954 is now available.

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C. E. Paules

F. L. Miller

A. D. Green

D. L. Campbell

W. F. Persons

▸ Six new executive position appointments have been anounced by Standard Oil Development Company. Named as deputy coordinators were **F. L. Miller, D. L. Campbell, W. F. Persons, C. E. Paules, R. M. Shepardson** and **A. D. Green.** They will serve as deputies to the six vice presidents who are responsible for coordinating specific phases of the firm's operations.

Miller is deputy to **W. C. Asbury** for patents, contracts, legal matters and public relations. He has been manager of the contract, legal and patent department since 1953. He joined the company in 1930 and his previous posts included that of director of the research division.

Campbell is deputy to **E. J. Gohr** for research and development work on fuel processes and analytical research. He has served as associate director of the process division since April. He joined the company in 1928 and holds several patents regarding fluid catalytic cracking refining techniques and manufacture of synthetic fuels.

Persons is deputy to **A. P. Hewlett** for general administration. He has been assistant director the employee relations department since 1950.

Paules is deputy to **E. W. Luster** for engineering. He has been chief engineer of the Esso engineering department since 1949. His service dates back to 1919.

Shepardson is deputy to **W. J. Sweeney** for petroleum products and medical research. He has been director of the process division since 1947 and joined the company in 1930.

Green is deputy to **C. O. Tongberg** for chemical research and process research on lubes and specialty products. He has been director of the development division since 1936. He joined the company in 1930 and his service included work on the development of processes for the manufacture of synthetic rubbers.

▸ **Dr. Carl O. Tongberg** and **Dr. Amiot P. Hewlett** have been appointed vice presidents of Standard Oil Development Company. Tongberg was previously coordinator of research and development on products. Hewlett was general administration manager. Tongberg was also named to the executive committee and elected a director. He has been with the company since 1937, serving in a number of positions including that of director of the research division.

Hewlett came with the company in 1930, after a period of teaching at several institutions including Georgia Tech where he was an assistant professor of chemistry. His positions included that of manager of the Process Division and Employee Relations Advisor to the parent company, Jersey Standard.

Appointment of **Stewart Schackne** as manager of the public relations department was announced today by Standard Oil Company of New Jersey. An assistant manager of the department since 1945, he succeeded **George H. Freyermuth.** Since 1935, Schackne has been in public relations work, including six years as publicity director of the Sonotone Corporation which he left in 1942 to join Earl Newsom and Company. He has been associated with the Jersey Standard public relations department since its inception in 1943, first as a consultant with Newsom and later as assistant manager.

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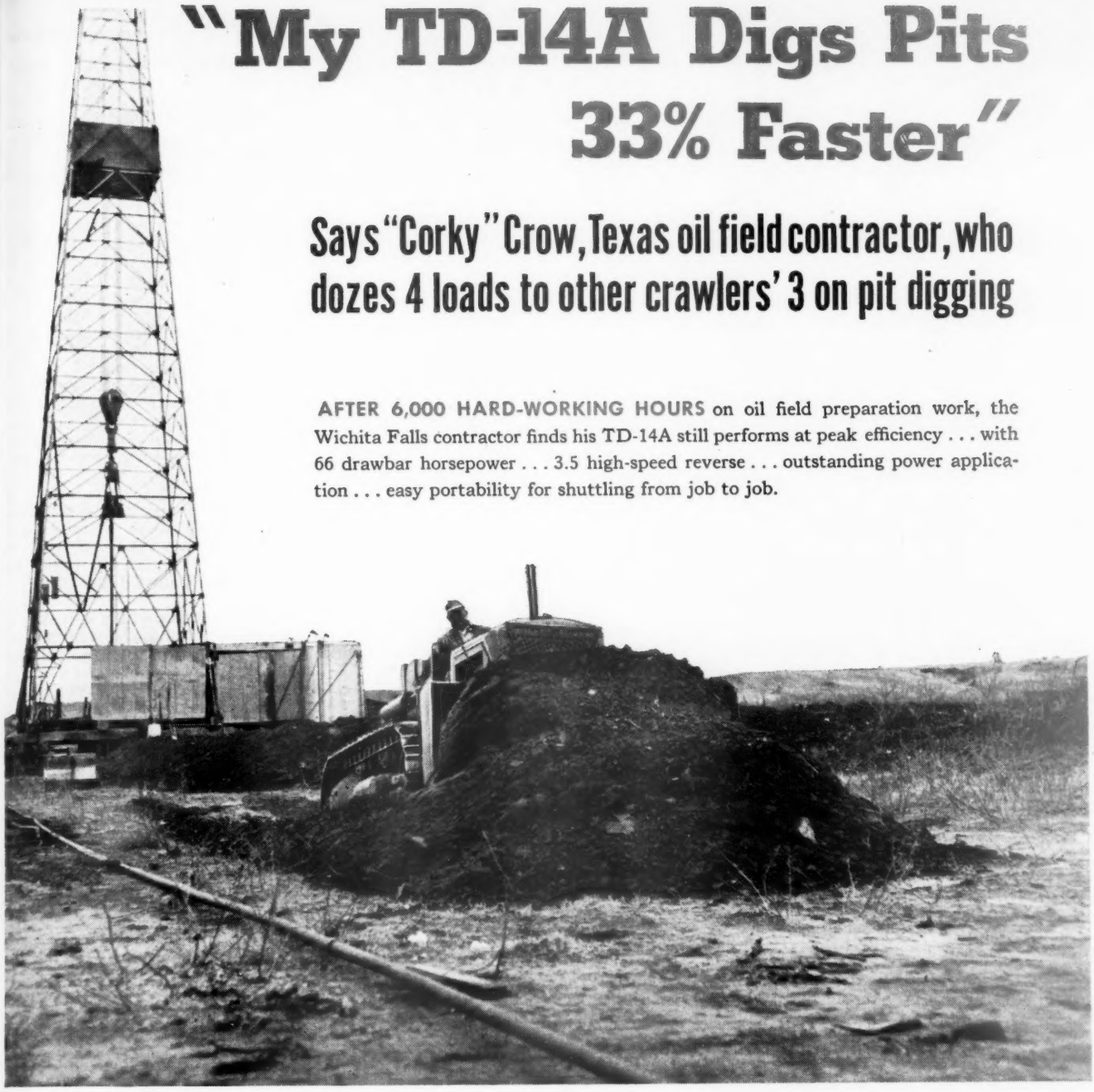
"My TD-14A Digs Pits 33% Faster"

Says "Corky" Crow, Texas oil field contractor, who dozes 4 loads to other crawlers' 3 on pit digging

AFTER 6,000 HARD-WORKING HOURS on oil field preparation work, the Wichita Falls contractor finds his TD-14A still performs at peak efficiency . . . with 66 drawbar horsepower . . . 3.5 high-speed reverse . . . outstanding power application . . . easy portability for shuttling from job to job.



In the booming oil fields around Wichita Falls, Texas, oil field contractor E. C. "Corky" Crow works his two INTERNATIONAL TD-14A tractors alongside other makes of crawlers.

Here's what he says about oil field crawlers:

"I come out of the pits with 4 loads with my TD-14As when other tractors working alongside only get 3 loads—a 33 percent bonus. I can move my TD-14As around from one job to another in a small truck at low cost. And they both have the guts to outwork anything of the same size. Give the drilling company a chance to choose a tractor for the job and mine are the ones they pick. Many a time I had to thank my IH crawlers for extra hours and days of profitable work."

That's one man's experience with INTERNATIONALS in the oil field—and your INTERNATIONAL Industrial Power Distributor would sure like to get yours. He'll demonstrate anywhere and any time you say so you, too, can see what "Corky" Crow was talking about. Call today.

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DEATHS

Paul E. Hurley, 53, manager of Shell Oil Company's Houston refinery died of a heart attack October 26, in New Orleans, Louisiana. He had been named manager of the Houston plant on August 1. For the past nine years he has been manager of Shell's Norco, Louisiana, refinery.

George Herbert Rupp, manager of the mining department of The Colorado Fuel and Iron Corporation, died recently in Pueblo, Colorado. He joined Colorado in 1929.

J. Paul Jones, assistant manager of the patent division of Phillips Petroleum Company, died of injuries suffered in a fall at his home in Bartlesville, Oklahoma. He had been a member of the research and development department at Phillips since 1934, and had several patents pertaining to the petroleum and chemical industry.

Ward E. Pratt, chemical consultant of centrifugal pump division, Worthington Corporation, died at his home in West Orange, New Jersey. Pratt had been with Worthington for 20 years. He received his ME degree from Cornell University.

Automobile deaths within two days of one another claimed the lives of two employees of Oil Base, Inc. **Bennett Hoffman (Ben) Burks,** 32, was killed in a car-truck collision near Laurel, Mississippi. In a similar car-truck accident, near Odessa, Texas, **William Harvey Petross,** 34, was fatally injured. Petross, who lived in Odessa, was district manager in West Texas. Burks was a sales engineer operating from the Houston office.

Harry O. Heller, advertising manager of Reed Roller Bit Company, died recently at his home in Houston, Texas. A former vice president of Southwestern Engraving Company, and the second president of the Houston chapter of the National Industrial Advertisers Association, he was a leader in the activities of this and other advertising and marketing organizations.

Frank M. Siebert, better known in the oil industry as "Doc" Siebert, for many years chief chemist for Gulf Oil's Houston production division, died in Houston, Texas, recently. He had been retired from the company for two years. Dr. Siebert was a chemical engineering graduate of Penn State College and received his Ph. D. from Princeton in 1914. Recognized as a pioneer in the field of oil and gas conservation, he figured prominently in the development of drilling methods and in the use of many other devices now accepted as routine conservation procedure. He was a specialist on drilling mud techniques.

Charles Eugene (Gene) Crawley, former president of the Sinclair Oil and Gas Company, died unexpectedly at his home in New York recently. He was also a vice president and a director of Consolidated Oil Corporation, owned by Sinclair, and later was with Merrill Lynch, Pierce, Fenner and Beane.

Reginald R. Brinkmann, president of the Highland Oil Company of Shreveport, Louisiana, and vice president of Triangle Refineries, Inc., of Houston, Texas, died recently. Death came at his Shreveport home after a brief illness.

Allowable External Working Pressures For 3S-H14 and Alclad 3S-H14 Tubes

The external working pressures given below are based on the theory developed in "A Study of the Collapsing Pressure of Thin Walled Cylinders" by R. G. Sturm, University of Illinois, Engineering Department, Engineering Station Bulletin, Series No. 329.

Nominal Outside Diameter, Inches	SPECIFIED WALL THICKNESS		ALLOWABLE WORKING PRESSURE, PSI., For Metal Temperatures Not Over				
	Inch	Stubs' Gage No.	100 °F or Less	200 °F	300 °F	400 °F	500 °F
⅝	0.049	18	675	580	455	290	155
	0.058	17	830	710	560	370	185
	0.065	16	950	810	640	415	210
	0.072	15	1065	910	720	460	230
	0.083	14	1250	1060	830	530	265
¾	0.049	18	530	460	360	225	120
	0.058	17	665	570	430	285	155
	0.065	16	765	655	515	335	175
	0.072	15	865	740	580	385	190
	0.083	14	1020	870	685	445	220
	0.095	13	1190	1010	790	505	255
	0.109	12	1380	1165	910	580	290
⅞	0.049	18	425	375	295	175	90
	0.058	17	545	470	365	225	120
	0.065	16	630	540	425	270	150
	0.072	15	720	615	485	310	165
	0.083	14	850	730	575	380	190
	0.095	13	1000	850	675	435	215
	0.109	12	1165	990	780	500	250
1	0.049	18	350	310	245	145	72
	0.058	17	450	395	310	185	96
	0.065	16	525	460	360	220	120
	0.072	15	605	525	410	260	145
	0.083	14	725	620	490	315	165
	0.095	13	855	730	575	380	190
	0.109	12	1000	850	675	435	220
	0.120	11	1115	950	750	480	240
	0.134	10	1265	1070	840	535	270
1⅛	0.049	18	285	255	205	120	60
	0.058	17	380	335	265	155	77
	0.065	16	435	390	305	185	95
	0.072	15	520	450	350	215	115
	0.083	14	625	540	425	265	150
	0.095	13	740	635	500	325	170
	0.109	12	875	735	590	390	195
	0.120	11	975	830	660	425	215
	0.134	10	1110	940	745	475	240
1¼	0.049	18	235	210	170	100	51
	0.058	17	320	280	225	130	65
	0.065	16	385	335	265	160	79
	0.072	15	445	390	305	185	95
	0.083	14	545	470	370	230	125
	0.095	13	650	560	440	280	150
	0.109	12	770	660	520	340	175
	0.120	11	865	735	580	385	190
	0.134	10	985	835	665	430	215
1⅜	0.049	18	195	180	145	87	46
	0.058	17	270	240	195	115	57
	0.065	16	330	290	230	135	66
	0.072	15	385	340	265	160	79
	0.083	14	475	415	325	200	100
	0.095	13	575	490	390	240	130
	0.109	12	685	585	465	295	160
	0.120	11	770	660	520	340	175
	0.134	10	880	750	595	390	195
1½	0.049	18	165	150	125	77	40
	0.058	17	230	205	170	99	50
	0.065	16	285	250	205	120	59
	0.072	15	335	295	235	140	69
	0.083	14	410	360	285	170	85
	0.095	13	510	445	345	210	115
	0.109	12	615	530	415	260	145
	0.120	11	690	595	470	300	160
	0.134	10	795	680	535	350	180
1¾	0.049	18	115	110	93	59	32
	0.058	17	165	150	130	78	40
	0.065	16	210	190	155	93	48
	0.072	15	260	230	185	110	55
	0.083	14	330	290	230	135	66
	0.095	13	405	360	280	170	84
	0.109	12	500	435	340	210	110
	0.120	11	565	490	385	240	130
	0.134	10	655	565	445	285	155
2	0.049	18	81	78	68	47	26
	0.058	17	120	110	96	61	33
	0.065	16	170	150	125	76	39
	0.072	15	200	180	150	79	46
	0.083	14	260	230	190	110	56
	0.095	13	335	295	235	140	68
	0.109	12	410	360	285	170	86
	0.120	11	475	415	325	195	100
	0.134	10	550	475	375	235	125

These computed allowable pressures are based on the nominal dimensions of the tube itself, with no allowance for efficiency of joints.

All figures are based on a factor of safety of 4.

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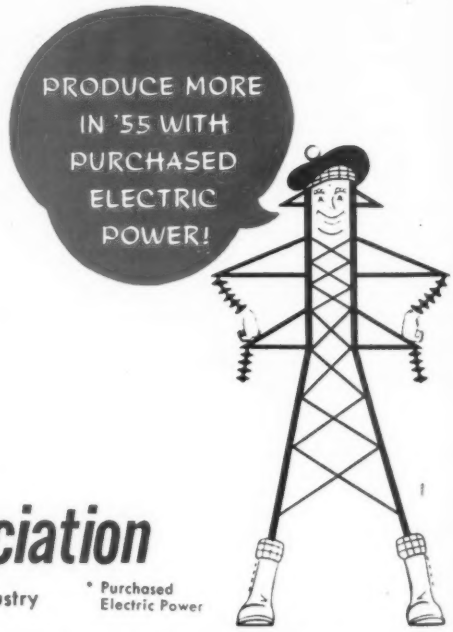
To secondary recovery operations, Purchased Electric Power brings dependable, 24-hour-a-day power at *lowest possible cost* . . . . just another instance which shows how PEP* is benefiting the Petroleum Industry.

Yes, PEP* works day and night — or operates on any fractional time schedule . . . . which means you pay only for power used. Upkeep and maintenance costs are lower, too . . . . which means that manpower and payroll costs are also cut to the bone.

Let Purchased Electric Power go to work for *you!* There's a Power Engineer at your nearest Electric Power Company who can give you the answers to all your power problems. Why not get in touch with him today?



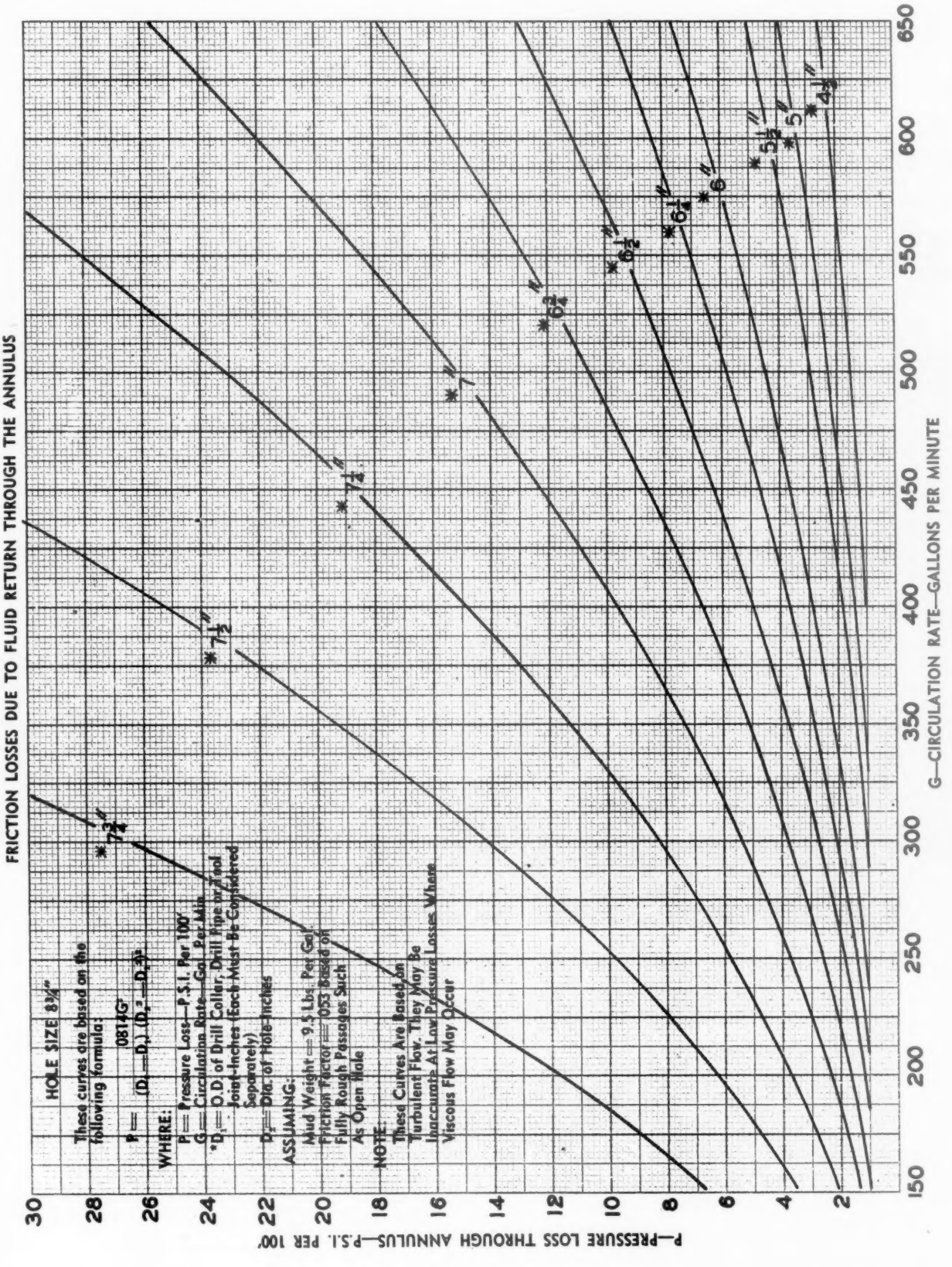
CALL YOUR NEAREST ELECTRIC SERVICE COMPANY for more facts, or address your request to P. O. Box 2771, Dallas, Texas

Petroleum Electric Power association

ORGANIZED in the interest of greater service to the petroleum industry

* Purchased Electric Power

DRILLING HYDRAULICS


FRICTION LOSSES DUE TO FLUID RETURN THROUGH THE ANNULUS
P—PRESSURE LOSS THROUGH ANNULUS—P.S.I. PER 100'
G—CIRCULATION RATE—GALLONS PER MINUTE
30 28 26 24 22 20 18 16 14 12 10 8 6 4 2
150 200 250 300 350 400 450 500 550 600 650
7¾" 7½" 7¼" 7" 6¾" 6½" 6¼" 6" 5½" 5" 4½"
HOLE SIZE 8¾"
These curves are based on the following formula:
P = .0814G² / (D₂−D₁)·(D₂²−D₁²)
WHERE:
P = Pressure Loss—P.S.I. Per 100'
G = Circulation Rate—Gal. Per Min.
*D₁ = O.D. of Drill Collar, Drill Pipe or Tool Joint-Inches (Each Must Be Considered Separately)
D₂ = Dia. of Hole-Inches
ASSUMING:
Mud Weight = 9.5 Lbs. Per Gal.
Friction Factor = .053 Based on Fully Rough Passages Such As Open Hole
NOTE:
These Curves Are Based on Turbulent Flow. They May Be Inaccurate At Low Pressure Losses Where Viscous Flow May Occur

Courtesy of Hughes Tool Company

new V-12

WAUKESHA

Diesel **VLR SERIES UNITS** *Gas*

TURBOCHARGED DIESEL — 1100 HP
LPG — 870 HP • NAT. GAS — 780 HP
NORMAL DIESEL — 800 HP

(Complete unit ratings—1200 rpm)

This powerful new Waukesha is a twelve-cylinder, high compression, overhead valve, 60-degree vee, four-cycle engine of 8½-inch bore and stroke, and 5788 cubic inch displacement. Connecting rods are side by side type; opposing pistons operating from a single wide-area crankpin. Bare engine ratings at 1200 rpm are: Turbocharged Diesel, 1135 hp; Normal Diesel, 830 hp; Butane-Propane, 900 hp; Natural Gas, 810 hp. Response to throttle and load requirements is quick and smooth, with a fast surge of reserve power for emergency and overload demands. Tremendous in power, remarkably rugged, the V-12 is designed for simplicity and reliability. Major parts are interchangeable between right and left cylinder banks. Main and rod bearings are easily accessible. Strength, precision and balance are built into all elements of the power train, from pistons to flywheel. Supporting members are designed for extreme rigidity and perfect alignment of moving parts. Send for Bulletin 1656.

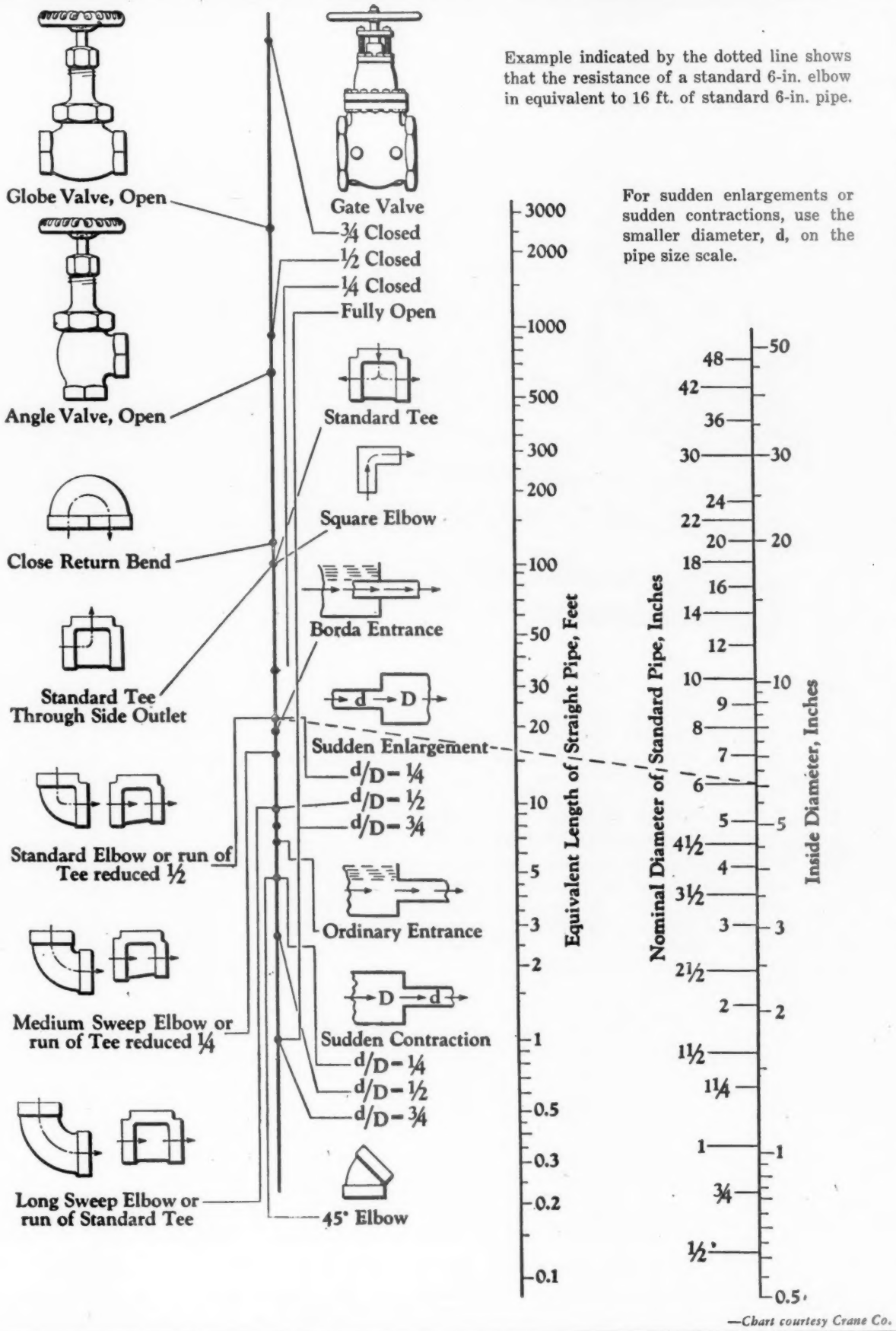
WAUKESHA MOTOR COMPANY

WAUKESHA, WIS.

NEW YORK • TULSA
LOS ANGELES

264

VALVE AND FITTING RESISTANCE TO FLUID FLOW



Aldrich-Groff Constant Stroke Pump, used in conjunction with the Variable Stroke "POWR-SAVR" to provide the desired base volume of delivery.

Aldrich-Groff Controllable Capacity "POWR-SAVR" Pump, applicable throughout the Petroleum Industry, is available in 6 frame sizes ranging from 5 to 125 hp for pressures from 250 to 15,000 psi, and provides stepless, automatic control of delivery.

ELIMINATE LINE PRESSURE SWING

Maintain Maximum Pipe Line Efficiency...

By combining an Aldrich-Groff Variable Stroke "POWR-SAVR" Pump with either its companion Aldrich-Groff Constant Stroke Triplex Units or an Aldrich Multuplex Pump, you can automatically eliminate line pressure swing and safely maintain the maximum rate of delivery in your line at all times. You can also simplify pump station control and eliminate the expense and objectionable features of station surge tanks.

The development of Aldrich-Groff Variable Stroke and Constant Stroke Pumps—to embody *interchangeable fluid-end* and *principal power-end parts* — constituted another notable Aldrich "First". These units are serving on a number of modern high pressure pipe lines with the satisfactory results indicated by repeat orders.

Variable Stroke Pumping Capacity need only cover throughput variations incident to temperature and viscosity changes. The bulk of the installed capacity may be of the less expensive Constant Stroke Units. Such a multiple unit installation not only affords pumping flexibility and extreme reliability, but also lessens the investment for spare unit capacity. And, pumping units need only be installed to care for initial line capacity with additional units being added as the line demands build up. This means less initial investment expense and attainment of full load efficiency under all conditions, with consequent savings in pumping power.

Both types of units employ a *conventional fixed throw crankshaft* of solid forged steel construction which has proven to be best adapted for reliable continuous service, as attested by over 500 units installed so far—many with 10 year service records.

Both units feature self-contained reduction gear drive adapted to utilize an efficient high speed motor or turbine (for refinery service) mounted on the pump frame itself. This not only means compactness of floor space and savings in foundation and building costs—but assures accurate mechanical alignment at all times. V-Belt and other forms of engine drive are optional.

Write for Data Sheet 65A or for our representative to call.

the ALDRICH *pump company*

. . . Originators of the Direct Flow Pump

26 PINE STREET • ALLENTOWN, PENNSYLVANIA

Representatives: Bushnell Controls & Equipment Co., Inc., 5137 West Jefferson Blvd., Los Angeles 16, Calif. • Cross Pump & Equipment Co., P.O. Box 889, Charleston 23, W. Va. • Lloyd T. Gibbs Co., 1021 Petroleum Bldg., Tulsa 3, Okla. • Lloyd-Smith Co., Inc., Bradford, Pa. • Walter Norris Engineering Co., Civic Opera Bldg., 20 North Wacker Drive, Chicago 6, Ill. • Power Specialty Co., P.O. Box 6365, 2000 Kipling Street, Houston 6, Texas; The Suburban Bldg., Room 204, 5526 Dyer Street, Dallas 6, Texas • B. G. Harmon Service & Equipment Co., P.O. Box 309 (Farm Bureau Bldg.) Carmi, Ill. • Stearns-Roger Manufacturing Co., 1720 California Street, Denver 2, Colo. • Export: Petroleum Machinery Corporation, 30 Rockefeller Plaza, New York 20, N. Y.

OIL and GAS TRADE NEWS

J&L Builds Plant

Jones and Laughlin Steel Corporation has announced plans for construction of a new container division plant and office at West Port Arthur, Texas. Equipment now used for producing steel drums will be moved into the new building, which will be about 38,000 sq ft in size. The present plant, where J&L has conducted operations since 1940, will be used for warehouse space.

Rusty Sub Revamped

The only submarine ever captured at sea by the U.S. Navy and the only enemy warship captured at sea by our Navy since 1815, the German Submarine U-505, is now being readied as a permanent display at the Chicago Museum of Science and Industry. Rust-Oleum was used to "dress-up" the once-proud German undersea "killer" which presented an extreme rust and corrosion problem in attempting to preserve the badly rusted hull for permanent display. In many places, the hull was rusted completely through. A Rust-Oleum primer coating penetrated the rust and formed the base and Rust-Oleum finished coatings in gray and green were applied.

G. E. Welding Plant Opened

Official opening of General Electric Company's welding plant in York, Pennsylvania, has been held. Result of long-term planning, plant is headquarters of G-E welding products and will be utilized to manufacture ac transformer, dc rectifier, dc motor-generator, and dc engine welders.

Thew Buys Dixie Stock

Arrangements have been completed by the Thew Shovel Company, Lorain, Ohio, for purchase of the controlling stock of Dixie Crane and Shovel Company, Inc., Harrisburg, Pa. Dixie Crane line will continue to be manufactured and distributed by Dixie Crane, under that brand name.

Bowen Names Representative

Paul Bowen, president of S. R. Bowen Company, announces the appointment of Oil Well Coring Services, Ltd. as Canadian representative, with headquarters at Edmonton, Alberta and branches at Calgary, Alberta, and Virden, Manitoba. Oil Well Casing Services sells and rents Bowen tools with particular attention to rental service.

Du Pont Plans Labs

Ten service laboratories have been completed recently or are now being built by the Du Pont Company. The 10 new units will cost more than $12,000,000. Several will be devoted to customer service and product development, others to long-range research. They supplement a $30,000,000 expansion of Du Pont's Experimental Station near Wilmington, finished in 1950, the Stine Laboratory, and the Haskell Laboratory for Toxicology and Industrial Medicine, completed more recently, and laboratories at 29 other locations.

Distributors Named

Worthington Corporation announces the appointment of six new distributors for the corporation's welding positioners and turning rolls. Distributors are Louisiana Welding Supply Company, Superior Welding Supply Company, Oxygen Service Company, Tennessee Welding Company, Jones Welding Supply Company, and Lake Welding Supply Company.

Ruberoid to Build Plant

Herbert Abraham, chairman of The Ruberoid Company, marked the 68th anniversary of the founding of his company by announcing that Ruberoid will start building a new plant in California within a short time. The plant, to be built on about 22 acres recently acquired in Los Angeles, will manufacture Ruberoid asphalt roofings and later may be expanded to produce asbestos-cement and other products.

Master Installs Crane

Master Tank and Welding of Dallas, Texas, has installed an 80-ton overhead crane in its tanks department. Crane was originally rated as 40 tons, but the engineers at Master redesigned and reinforced the bridge to carry the additional load. Weight of crane exceeded 30 tons.

Tuloma Awarded Contract

First contract awarded to Tuloma Builders, Inc., of Tulsa, Oklahoma, since its organization in mid-August, is for the building of 11 metering stations in central Iowa for Northern Natural Gas Company. Top personnel of Tuloma formerly were with Midwestern Constructors, Inc., and all work formerly handled by Midwestern's engineering and plant construction department will be handled by Tuloma.

'Oilwell' Opens Branch

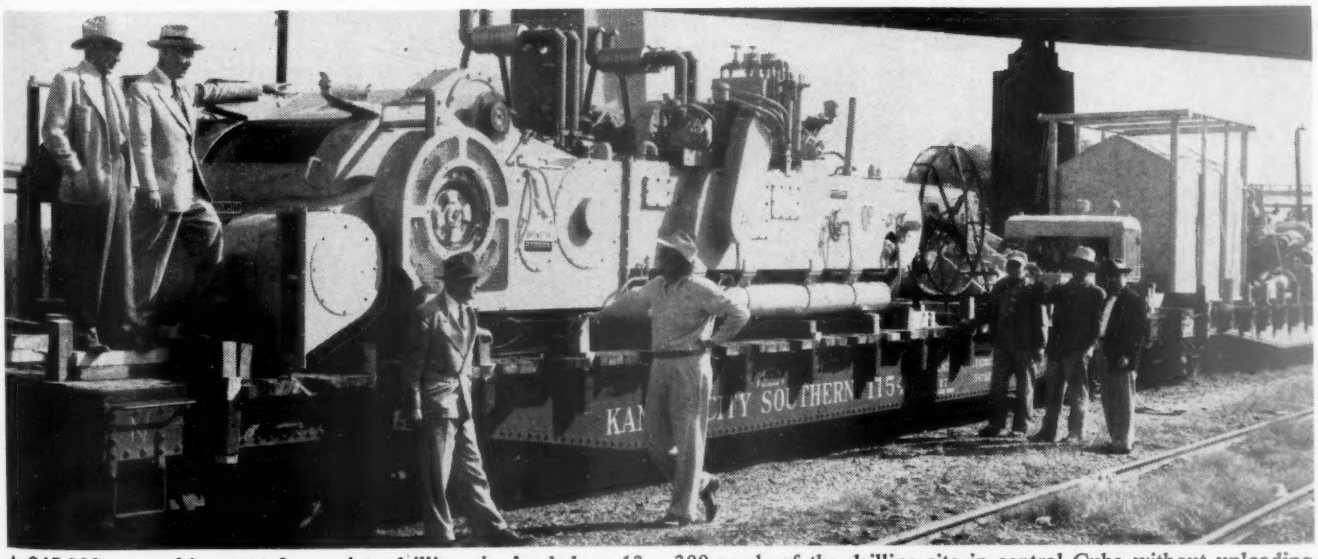
Opening of a new branch store at Medicine Lodge, Kansas, has been announced by U. S. Steel's Oil Well Supply Division. A combination branch store and warehouse, the unit was established to expand "Oilwell's" service to the rapidly expanding drilling and production activities in that area. Raymond H. Miller is store manager and Lewis Y. Poland is field representative.

Hamer Names Representative

The Ralph H. Stockton Company has been appointed exclusive sales agents for Hamer Valves in southern Texas. Company will make its headquarters in Houston, Texas.

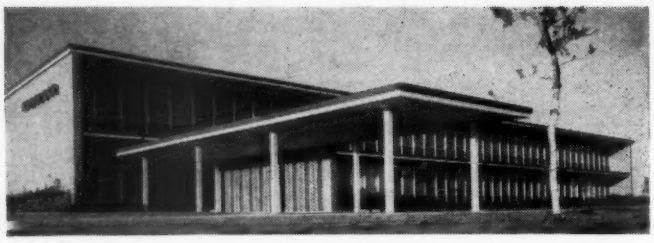
Mid-Continent Opens Store

Mid-Continent Supply Company has announced the opening of a new store in Andrews, Texas. Store is the standard all-steel Mid-Continent field store and is equipped with two-way radio as a part of Mid-Continent's West Texas-New Mexico network. W. D. Purtell is manager.



A $45,000 mass shipment of complete drilling rig, loaded on 13 flatcars, is inspected by officials of Jones Brothers, Inc., drilling contractors, the Brewster Company, oilfield equipment manufacturer which outfitted the rig, and Kansas City Southern Railways, before it pulled out for West Palm Beach, Havana, and to within 300 yards of the drilling site in central Cuba without unloading. With equipment to sustain operations for two years, the rig will launch Cuban wildcat drilling operations for Jones Brothers, Inc. on a 17-million acre tract for Trans-Cuba Oil Company, SA. Drilling site is near Ciego de Avila in central Cuba.

Magnet Cove Opens Houston,



Magcobar held a gala formal opening of its new office and laboratory building. The building is of modern design with end walls of brick, and north and south all-window curtain walls. Site is 3403 Buffalo Speedway, Houston.

Hosts for the open house were the board of directors of Dresser Industries, Inc., pictured below. In front row, left to right, are J. B. O'Connor, executive vice president of Dresser, Willard M. Johnson, president of Magcobar and vice president of Dresser, H. N. Mallon, Dresser president. In the back row are C. W. Clark of Clark Brothers, director of Dresser, R. E. Reimer, Dresser secretary and treasurer, W. A. McAfee, Standard of Ohio vice president and Dresser director, and H. P. Isham, Clearing Industrial District, Inc. and director of Dresser.

C. P. Clark, president of Clark Brothers Company, Don L. Connelly, vice president of Warren Petroleum, and John O'Connor, Dresser executive vice president, inspect facilities of the Houston headquarters buildings.

Among the guests were Mrs. George W. Gist, Rex Hamaker of Reed Roller Bit Company, Mrs. Sid Brewster and Sid Brewster of Brewster-Bartle Drilling Company, and George W. Gist of Wilson Supply Company.

Dresser officials H. P. Isham and H. P. Boncher pictured with W. A. McAfee, director of Standard Oil of Ohio, appear justly proud of their two-story brick and glass structure, 29,360 square feet in area.

XUM

Barium Corporation Texas, Headquarters

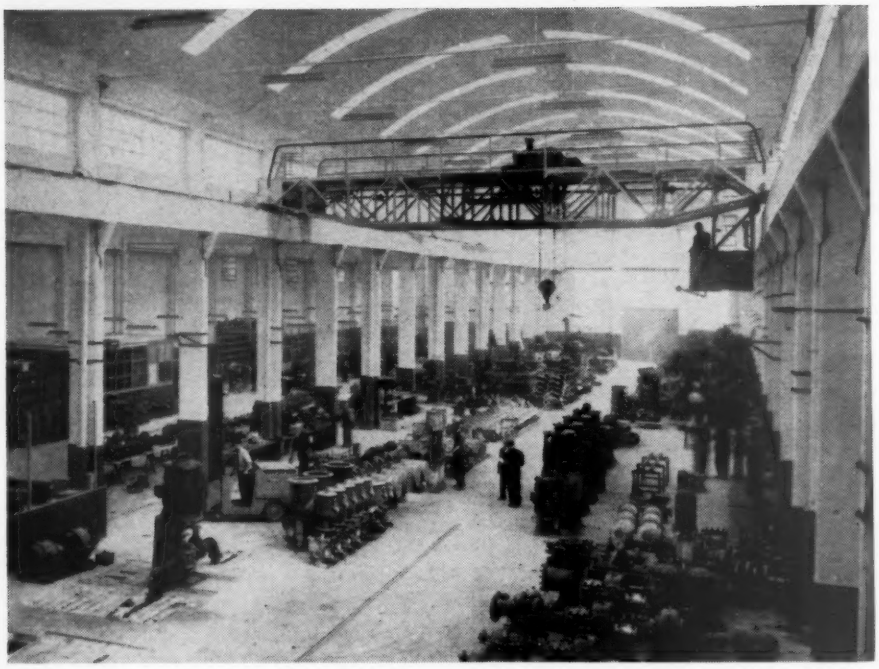
M. E. Hankins, purchasing agent for the Texas Company, is briefed by Macogbar President Johnson, above, who was a founder of the company in 1940.

Phillips Petroleum's Roy Bobo, and wife, comparing notes on the Magcobar building features with Magcobar Comptroller Floyd Enz and Mrs. Enz, on hand for the opening.

Three visitors at the opening of Magcobar's facilities are George Kitchell, vice president of Kerr-McGee Oil Company, Mrs. George Kitchell, and M. E. Montrose of Hughes Tool Company, shown above.

Below are R. R. McLaughlin of Rheem Manufacturing Company, Geoerge E. Tyson of J and L, Jack Knight of Reed, and Warren Cunningham, attorney.

Seen below are Mrs. J. W. Burhart, Joel Battle of the Texas Company, L. D. Jones of Magcobar, Fred Wise of Humble, and J. W. Burhart of Texas Eastern.



Worthington Corporation's new plant recently opened in Madrid, Spain. The plant consists of three factory bays occupying 45,000 square feet.

Distributors for Bits Named

Herb J. Hawthorne, Inc., Houston, Texas, manufacturers of Blue Demon Exploration Drilling Bits, has announced the appointment of four new distribution outlets in the Rocky Mountain Area. Anderson Seismograph Bit Service, with stores in Casper, Wyoming, Grand Junction, Colorado, and Sidney, Montana; and O'Tool Company, Cortez, Colorado, will distribute the cutter bits.

New Service Organized

Organization of an integrated engineering group to provide a complete engineering service for the design, construction, and installation of industrial recording and control systems is announced by Berkeley division of Beckman Instruments, Inc., Richmond, California. Headed by Wallace E. Rianda, the group offers services including consulting engineering, design, construction, supervision of field installation, and preparation of operating and service manuals for complete systems, and providing a source of coordinated responsibility for the satisfactory completion of systems installations.

McCullough Opens Branch

McCullough Tool Company has announced the opening of a branch service location at Cut Bank, Montana. Branch will serve the area with all wire line and fishing tool services of the company. Dallas Novak has been appointed branch manager.

Dow Opens Office

The Dow Chemical Company announces the opening of a Chicago Terminal Office to provide improved customer service in the distribution of its products in a six-state marketing area including Minnesota, Wisconsin, Iowa, Illinois, Indiana, and Michigan. In line with its expansion in the Chicago area, the company has just added new storage facilities at General American Tank Storage Terminals to its distribution network.

Ohio Oil Wins Award

The National Safety Council's Award of Merit has been presented to the Marathon retail sales department of Ohio Oil. Presentation marked the second consecutive year the department received the award.

Pemco Adds Equipment

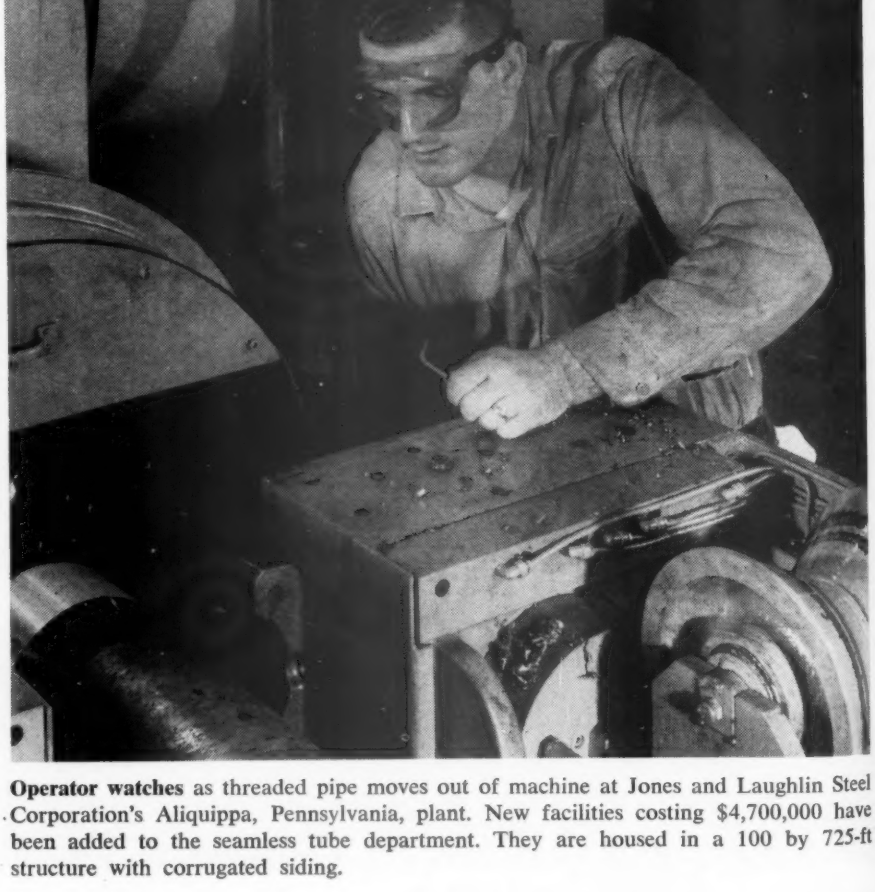
Process Engineering and Machine Company has announced expansion of its heat exchanger retubing and repair department. As part of its expansion of heat exchanger manufacturing and repair facilities, Pemco has tooled up with the most modern retubing equipment for shop and jobsite work. When required, the code status of equipment is maintained intact by the use of code approved repairs, which provide for code welding, testing, inspection, and restamping.

Distributors Appointed

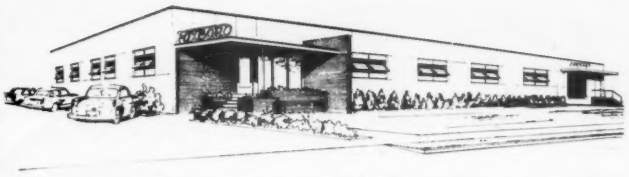
Baldwin-Lima-Hamilton Corporation, Construction Equipment Division, Lima, Ohio, announces the appointment of two distributors for the sale of Lima shovels, cranes, draglines, and pull shovels. R. S. Armstrong and Brothers Company of Albany, Albany, Georgia, has been named distributor covering the southern portion of Georgia. The distributorship for the northern portion of Texas has been assigned to Fred Berryhill Equipment Company, Inc., Lubbock, Texas.

Rockwell to Build Plant

Rockwell Manufacturing Company has announced the selection of Russellville, Kentucky, as the site for a new plant expected to go into operation in mid-1955. The plant will be located on a 30-acre site and will have from 80,000 to 100,000 square feet of floor space. It is expected to cost from $800,000 to $1,000,000, exclusive of production equipment. Plant will be a one-story brick and tile building with a natural gas air conditioning system.



Operator watches as threaded pipe moves out of machine at Jones and Laughlin Steel Corporation's Aliquippa, Pennsylvania, plant. New facilities costing $4,700,000 have been added to the seamless tube department. They are housed in a 100 by 725-ft structure with corrugated siding.



A new instrument service and assembly building has been opened in San Leandro, California, by the Foxboro Company. The factory, with 8400 square feet of space, more than doubled the company's west coast manufacturing facilities. The building is designed of pre-cast concrete and houses services, production and sales departments.

Private Works Program Upheld

Benjamin F. Fairless, chairman of the board of United States Steel, sounded a warning against those "misguided gentlemen" who would seek to throttle America's private works program. Fairless declared that the billions upon billions of dollars that individual Americans have invested in job-producing facilities in every field of enterprise constitute, in effect, an enormous private works program which has created nearly all of the 62 million jobs that exist in this country today. Only through the steady enlargement of this program, he said, can the problem of unemployment be permanently solved.

General Precision Negotiating

General Precision Equipment Company, New York, is negotiating for control of Griscom-Russell Company, Massillon, Ohio. Under terms of an agreement with a majority of shareholders in Griscom-Russell, General Precision will exchange a portion of its stock for stock in Griscom-Russell. If consummated, the agreement will result in a transfer of control to General Precision. It is planned that Griscom-Russell will continue to operate as a separate corporation with its present management and location. General Precision now includes 18 subsidiaries.

How Many Teeth?

A contest will be held during the seventh annual convention of the Pipe Line Contractors Association which convenes at the Statler Hotel in Los Angeles on January 17 to 19. Prizes will total over $3000. Various sizes of H & L teeth will be displayed in a cabinet and persons guessing the closest to the actual number of teeth in the cabinet will win awards. A judging committee will tabulate the ballots. Awards will be presented to the winners by E. L. Launder, president of H & L Tooth Company, at a banquet on January 19.

Republic Adds 3 Stores

The Republic Supply Company has opened three new stores, making a total of 46 stores and 12 sales offices now in operation. The store at Palestine, Texas, is managed by Odie F. Reeves, Jr., formerly field salesman at Shreveport, Louisiana. The Healdton, Oklahoma, store is managed by R. Neill Griffith, formerly store manager at Nocona, Texas, and at Elmore City, Oklahoma. The Lindsay, Oklahoma, store is managed by Richard Evans, Jr., formerly field salesman at Elmore City.

Pazdral Representative

Tod Pazdral Pipeline Specialties has been appointed representative for the Holcombe Company, Inc. Tod Pazdral, president of the company, with 27 years experience in the pipe line industry, offers service in consulting, internal cleaning, inspecting, and testing.

Tool Joint Work Speeded

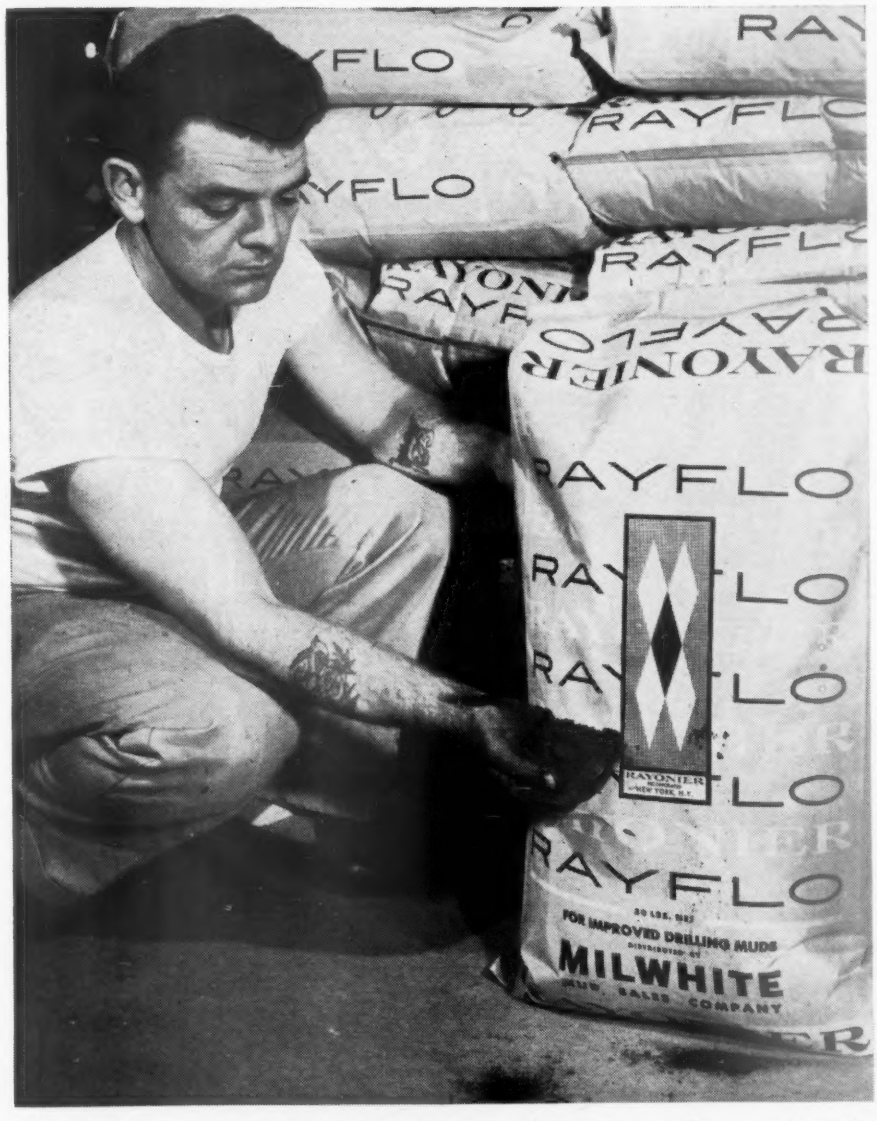
A steel-frame trailer, carrying 11 portable furnaces and 4 propane gas tanks, enables Elmer J. Daman, tool joint serviceman for The National Supply Company, at Olney, Illinois, to save much time in replacing worn-out tool joints for drillers in the Illinois, Indiana, and Kentucky oil fields. Damon does his work at the drilling rigs, rather than shipping the heavy drill pipe back to a central shop to change the joints. Often the work can be scheduled for times when the pipe is not needed for drilling. Furnaces on the trailer were designed by National Supply's engineering department and weigh 37 pounds each.

Corrosion Company Opens Plant

Corrosion Services Incorporated, a newly incorporated Oklahoma company, has opened a plant and offices on Sand Spring Road, Post Office Box 7343, Tulsa, Oklahoma. Company will distribute a number of nationally known products for corrosion mitigation and will also serve as a consulting service on corrosion problems to industry throughout the United States. Yale W. Titterington, Hugh Brady and Hartley Davis are officers of the new company.

J & L in New Plant

Operations at Jones and Laughlin Steel Corporation's new warehouse and container plant in Lancaster, Pennsylvania, began in December. The 100,000-sq ft area of the building is divided about equally between the warehouse and the Container Division Plant. The warehouse carries a full line of J&L steels. Materials-handling equipment includes an overhead traveling crane and a mobile crane. The container division plant manufactures 5-gal and 3½-gal steel shipping pails. Building includes office space for both operations.



This red-brown powder, called Rayflo, is a new dispersant, or thinner produced by Rayonier, Inc. Rayonier has announced two distributors for the polymeric polyphenol product: Milwhite Mud Sales Company, Houston, Texas and Macco Corporation, Paramount, California.

VISCO
REG. U.S. PAT. OFF.
OIL TREATING
507
COMPOUND
55 U. S. GALLONS
VISCO PRODUCTS CO. Inc.
HOUSTON, TEXAS
VISCO
HOUSTON TEXAS
VISCO

NEW oil and gas Equipment

- **Machinery**
- **Supplies**
- **Services**

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

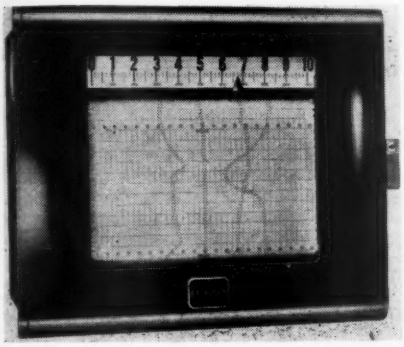
(1) HEATFLEX

A copper-clad electrical heating element called Heatflex is being produced by Continental Electric Equipment Company. The element, designed to be formed without tools, is recommended for keeping heavy oils or viscous materials flowing and for removing or preventing ice formations. It is said to be safely immersed in any solution not corrosive to copper and also can be operated at temperatures below freezing to 482 F.

Circle number (1) on reply card.

(2) COMPENSATOR

A device for changing reference junction compensators when going from one type of thermocouple to another is now available on Bristol Company's electronic



dynamaster multiple-point pyrometers. The new dynamaster development is a small, cylindrical aluminum piece, with an opening in one end into which a compensating resistor can be inserted.

Circle number (2) on reply card.

(3) DETECTOR

A new holiday detector, known as the model M-1 holiday detector, has been announced by Tinken and Raser. It was designed for locating holidays (pin holes, voids, etc.) in thin films of relatively high electrical resistance when such films are applied to the surface of material of low electrical resistance, such as metal or concrete. Detector is provided with a bell signal to indicate the flaw and has a dampened sponge for an exploring electrode.

Circle number (3) on reply card.

(4) AIR-GRIP

Dodge Manufacturing Corporation has announced production of a new air clutch, the Dodge Air-Grip. A minimum of air is used in the operation of the clutch which is said to provide "finger-tip" control and an ability either to "inch" the clutch or to throw it into full engagement. Clutch has internal ventilation and flexible air seal disc located so that it does not come in contact with heat generating plates. Provision is also made for mechanical engagement of the clutch.

Circle number (4) on reply card.

(5) PLASTICS

Hermes Plastics, Inc., is producing a flexible laminated plastic, gravoflex, for use in engraving. Lettering cut through the top layer of the sandwich material will stand out permanently on contrasting background, manufacturer said, and marking will not be distorted by bending or forming. Gravoflex is available in sheets, strips or cut name plates in various thicknesses. 1/32, 1/16, or ⅛-in. Colors are black surface with white core; white surface with red core.

Circle number (5) on reply card.

(6) END WRENCH

A new end wrench has been added to the line of heavy duty pipe wrenches of the Toledo Pipe Threading Machine Company. Features of the wrench include a new-type single spring that will not hang up on small sizes and assures quicker, easier setting of jaws, an easy-action nut, improved handle design, pipe scale on hookjaw.

Circle number (6) on reply card.

(7) MAGNETIC METER

An electromagnetic flow meter, designed for 2 to 8-in. flow lines, has been introduced by The Foxboro Company. Instrument is said to be additionally rated for unlimited maximum flows, making practical a number of flow measurement applications. Meter will measure the volume flow rate of any liquid of sufficient conductance and velocity. It is recommended for aqueous solutions, slurries, acids, and other corrosives, in addition to food and drug products requiring sanitary processing. The unit consists of a nonmagnetic flow tube with an insulating liner containing flush-mounted metallic electrodes and surrounded by an AC electromagnet.

Circle number (7) on reply card.

(8) PACKING SELECTOR

A packing selector designed for the layman to pick out the right packing for almost any application has been developed by New York Belting and Packing Company. The selector, a cardboard disc six inches in diameter, is said to be not only speedier than the present method of hunting through packing catalogs, but more accurate. Shown on the selector are packing styles, pressure and temperature readings for four types of packing application, i.e., gaskets, valve stems, and centrifugal and reciprocating pumps.

Circle number (8) on reply card.

(9) LINE BLIND

A new OS & Y type gate valve line blind that has no bolts to loosen and requires no lifting of plates by the operator, is being produced by the Greenwood valve division of Vernon Tool Company. Blind operates on the gate valve principle. It is available in larger sizes.

Circle number (9) on reply card.

(10) TRI-CLAD "55" MOTOR

Tri-Clad "55" motors, designed to feature extra protection for hazardous-location applications, have been announced by the small integral motor department of the General Electric Company. Available in ratings from 1 to 5 hp, motor is especially designed for safe applications in classified atmospheres containing flammable gases or combustible dusts. New motor has heavier frame and end shield castings, and a special, machined-fit conduit box.

Circle number (10) on reply card.

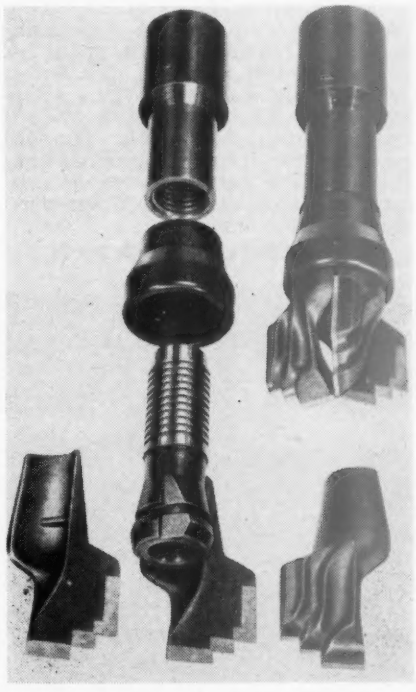
(11) PIPE LINE SCRAPER

Harsco pipe line scraper unit has been designed to force pipe line scrapers or pigs through pipe lines under conditions which vary greatly. Machine is a Model VG4D (36 hp) Wisconsin air-cooled heavy duty engine connected to a high pressure Roper rotary pump through an industrial transmission with 3 forward speeds and a reverse. The capacity varies from 15 BPH at 1000 lb to 65 BPH at 400 lb.

Circle number (11) on reply card.

(12) INSERT BIT

An insert rock bit designed to improve the efficiency of rotary drilling in seismic exploration has been developed by Herb J. Hawthorne, Inc. Bit is said to drill efficiently 95 per cent of all formations encountered in seismic exploration drilling.



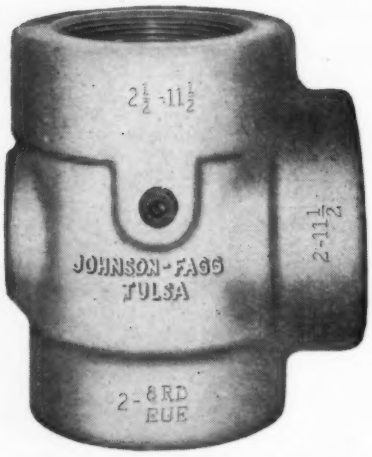
Bits were developed on interchangeable, replaceable blade design, permitting the use of many sets of blades with the same bit body.

Circle number (12) on reply card.

XUM

(13) PUMPING TEES

A series of new pumping tees is being offered by Johnson-Fagg Engineering Co., Tulsa, Oklahoma. One innovation of



the pumping tee design is a pipe plug outlet placed so that a pressure gage or chemical line may be attached to the tee without extra and expensive fittings.

Circle number (13) on reply card.

(14) AIR HYDRO PUMP

Davies Brothers has added a new pump to its line of air hydro pumps. New pump has a ratio of 690 to 1 and was designed to produce hydraulic pressure of 60,000 psi, with air 100 psi. Pump produces hydraulic pressure by means of a small volume of compressed air. It is made mainly of non-ferrous metals with the body being made of bronze and the ram of monel metal. The single acting pump has a 37-in. overall height and the double acting pump, 56-in.

Circle number (14) on reply card.

(15) WHITE TAPE RULE

The Lufkin Rule Company has added a new tape rule with a white blade graduated in both fractions of inches and 10ths and 100ths of feet. Blade of Lufkin White Clad Mezurall is finished in pure white with bold black figures and black graduations and coated with a clear abrasion resistant plastic. It has self adjusting end hook. Rule also features a case, die cast from magnesium alloy, with a non-glaring satin chrome finish.

Circle number (15) on reply card.

(16) OIL WELL REAMERS

Grant Oil Tool Company is featuring line of oil well reamers designed to handle the entire range of reaming operations. Line includes a three-point, near-bit reamer with one set of cutters for assuring full hole gauge as the bit wears, and for use as a fulcrum in directional drilling where drill collar support is required near the bit; a three-point regular reamer with one set of cutters in the middle of the body for reaming and stabilizing in normal drilling; and a six-point stabilizer reamer with two set of cutters staggered so as to contact a greater section of hole. This latter is especially adapted for reaming just before setting pipe. Grant's nine-point reamer with three sets of staggered cutters is specifically designed for straight-hole drilling in hard formations. The bodies of these reamers are of streamline design and are designed to be run into the hole with either end up. Cutters are set at an angle to give maximum shearing action.

Circle number (16) on reply card.

(17) MUD COMPOUND

A new oil well drilling mud compound, said to cut drilling time by at least ten days from the average time previously required for wells of similar depth and location, has been introduced by Monsanto Chemical Company's organic chemicals division. The new material, called Filcon SPF, stabilizes the viscosities and gel strengths of drilling muds by a new principle, according to a company bulletin. It also helps to reduce water loss in all types of mud. Filcon SPF is especially adapted for drilling salt or anhydride sections.

Circle number (17) on reply card.

(18) LUBRICANT

"Big 'D' Dope," a lubricant-seal for all types of threaded fittings, has been developed by C. H. Dragert Company. Single application of new thread compound is said to provide permanent lead-plating, island high, permitting repeated, easy quick assembly and disassembly of any size threaded connections without redoping, and without damage to threads. Company warrants compound to be anti-gall, non-corrosive, non-hardening and leak-proof and resistant to steam, gas, oil. air, chemicals, alkali, acids, ammonia and all hydrocarbons, under the most punishing pressures, temperatures and vacuums.

Circle number (18) on reply card.

(19) DuMONT BASE STATION

DuMont Laboratories' Types MCA 450-A and MCA 451-A are base stations incorporating transmitter, receiver, termination panel and power supply for two-way communications in the 450-470 Mc UHF band. Type MCA 450-A operates in the 450-460 Mc commercial band, while the Type MCA 451-A operates in the 460-462 Mc and 468-470 Mc Class A citizens' band. Types MCA 450-A and MCA 451-A incorproate facilities for local and/or remote operation. Special termination panel permits control through 2-wire or 4-wire telephone lines.

Circle number (19) on reply card.

(20) FORK-LIFT

Sherman Products, Inc., is marketing a fork lift attachment for tractors for mechanized material handling on off-pavement surfaces. Fork-Lift, designed for use on Ford tractor, was planned to be operated on unpaved or rough terrain by industries that cannot utilize the standard industrial fork lift truck. The attachment operates hydraulically and is said to lift a load up to 4000 lb 10 ft into the air. By means of reversed steering and driver's seat, the lift moves in exactly the opposite direction from a normal tractor, the conventional rear wheels becoming the forward wheels.

Circle number (20) on reply card.

(21) SUMP PUMP

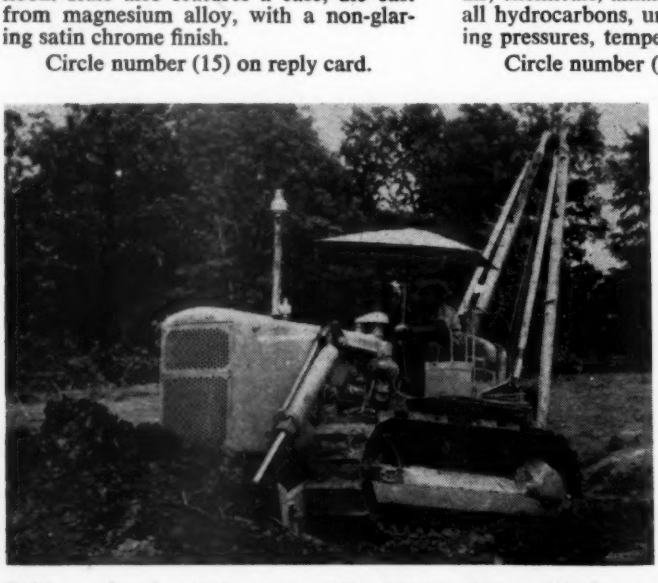
Schramm, Inc., has developed a pump to remove water from trenches and excavations. The pneumatic sump pump can be dropped in the water, eliminating priming and it can be operated by 105 or 125 cfm compressor.

Circle number (21) on reply card.

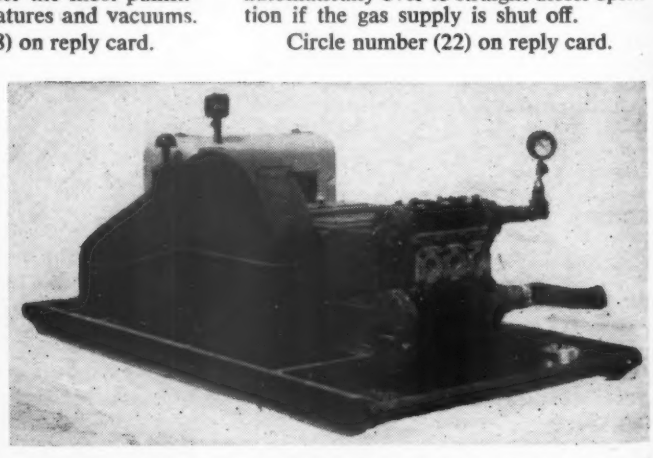
(22) DIESEL ENGINES

New line of General Motors Series 567-C diesel engines is available for industrial and petroleum applications through Stewart and Stevenson Services. Diesel is available in 600 to 1750 hp. A V-type cylinder arrangement is used to permit the application of the engine where space requirements are limited. Model 567-C can be furnished with equipment for dual fuel operation on either diesel fuel or natural gas. It is designed to go from dual fuel operation on natural gas automatically over to straight diesel operation if the gas supply is shut off.

Circle number (22) on reply card.



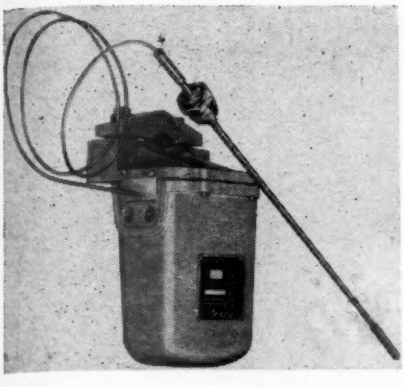
Balderson Inc. has designed an angling blade bulldozer, left, for use with the Caterpillar 74-in. gage D6 tractor. It is built to attach to the engine frame of the tractor and uses Caterpillar hydraulic or cable controls.



Production service jobs such as well killing, salt water and oil transfer, testing and breaking down formations are performed for Shell Oil Company at Kilgore, Texas, by the National Type F-60 triplex.

(23) TRANSMITTER

Model 12 A temperature transmitter that measures process temperatures and pneumatically transmits the information to a central recording or controlling station has been announced by The Foxboro Company. It is a nonindicating device of the "force balance" type with a calibrated



accuracy of ½ per cent of the temperature span and compensated for ambient temperature and barometric pressure variations. Spans ranging from 50 F to 400 F are available and can be utilized between the limits of — 100 F and + 1000 F.

Circle number (23) on reply card.

(24) SEISMIC SYSTEM

Houston Technical Laboratories is producing model 7000 seismic amplifier system designed with high gain, low distortion system for magnetic recording as well as conventional seismic applications. System incorporates three automatic gain control speeds with a 1,000,000 to 1 agc control range. In addition to agc operation, it also may be operated on constant gain or time varied gain. Total system gain is over 120 decibels, with input range from 0.1 microvolt to 0.1 volt between 10 and 200 cycles. Filter settings total 1380. Module design and lihgtweight construction limit maximum weight of any one element to 57 lb, with the 50-trace recording oscillograph weighing 41 lb. Components are equipped with carrying handles or optional back-pack adapters.

Circle number (24) on reply card.

(25) ALDRICH PUMP

A pump called "POWR-PAC" has been developed by The Aldrich Pump Company. New unit is a 2½-in. stroke, 25 hp, direct flow triplex pump, with direct flow fluid-end principle.

Circle number (25) on reply card.

(26) PVC VALVES

The Lunkenheimer Company has announced the first all-molded PVC valves and fittings. This line has been patented and registered under the name Luncor, which refers to its resistance to corrosive chemical action. Molding process is said to give the PVC material exceptional strength and protect its corrosion-resistance.

Circle number (26) on reply card.

(27) OYLTITE-STIK

Lake Chemical Company is producing cement in stick form, called Oyltite-Stik, for emergency sealing of oil leaks, cracks and other flaws or rusty parts in welds of fuel oil containers, storage tanks, pipe or containers.

Circle number (27) on reply card.

(28) CONOCONTROLS

Conoflow Corporation has announced the publication of catalog H-1, on pneumatic regulators, relays, and filters. Equipment and suggestions for its use are given in photographs and drawings in the 12-page catalog.

Circle number (28) on reply card.

(29) CATHODE RAY TUBE

International Business Machine Corporation terms its Type 740 cathode ray tube output recorder "windows" into which engineers and scientists can peer to see exactly what goes on inside the "giant brains" of its calculators. The new device was designed for use with IBM's Type 701 and 704 electronic data processing machines.

Circle number (29) on reply card.

(30) AUTOMATIC BLENDER

Proportioneers, Inc., division of B-I-F Industries, Inc., has developed a two-component blender specifically designed to provide industry with a complete equipment package for on-stream blending. A simplified standardized unit, blender is designed for such applications as caustic dilution, asphalt blending, cutting of heavy fuel oil, and blending of butane and gasoline.

Circle number (30) on reply card.

(31) VALVES

Paul Valve Corporation has announced production of a self-actuating regulating valve for product pipe line services. It features steady response to flow and pressure changes with linear throttling characteristics. Applications of the valve are for delivery terminal take-off, pump discharge regulation, and pump suction regulation. Valves are made in sizes from 3 to 12 inches, 600-lb pressure series.

Circle number (31) on reply card.

(32) LIQUID METER

Neptune Meter Company's auto-switch meter features a built-in, explosion-proof electrical switch that is actuated automatically when any desired quantity of liquid has passed through the meter. The switch can be used to turn pumps on or off, actuate solenoid valves, start agitators, or control other cycling operations by use of suitable relays, etc., and is available either with or without the mechanically coupled auto-stop valve.

Circle number (32) on reply card.

(33) THERMOCOUPLE

The development of a new type of thermocouple used for measuring rapid temperature changes of metal wall surfaces has been announced by Midwest Research Institute. The instrument is applicable for recording temperatures in such equipment as gun bores, cylinder and piston walls, brake drums, aircraft skins, autoclave walls and air ducts.

Circle number (33) on reply card.

(34) GASKET CONSTRUCTION

A new development in gasket construction, produced by Crane Packing Company, is said to eliminate flow restriction and turbulence in the line, as well as danger of gasket rupture at high temperature due to entrapped air between insert and envelope. The FreeFlow gaskets are especially recommended by the manufacturers for service in glass-lined, porcelain and pyrex equipment.

Circle number (34) on reply card.

(35) ENGINE POWER UNIT

Four Power Giant industrial engines produced by Willys Motors, Inc., are now being installed into a completely operatable engine package—the Willys power unit. It is equipped with a radiator, gas tank, air cleaner, complete electrical equipment and governor. The enclosure is a heavy gauge, steel housing. Unit is mounted on heavily reinforced skids and any of the 4 Willys industrial engines can be assembled into the unit.

Circle number (35) on reply card.

(36) GASOLINE ENGINE

Kohler Company's model K160, a four-cycle, air-cooled, gasoline engine, rated 6.6 hp at 3600 rpm, is available with electric starting. Engine is equipped with a 6-volt electric starter and generator, ignition switch, and starter button.

Circle number (36) on reply card.

(37) RADIO UNIT

The addition of a 25-watt mobile combination transmitter-receiver to its line of two-way radio communication equipment has been announced by the General Electric Company. The new two-way radio unit, which operates in the 152-174 megacycle band, was designed to work from either a 6 or a 12 volt battery.

Circle number (37) on reply card.

(38) TANK TRUCK

Master Tank and Welding Company has presented a tank truck with all working parts mounted as a single unit on the platform at the rear of the tank. Company notes that operator can make quicker delivery with only three steps; and that the entire tank unit can be changed from one truck to another in 60 minutes or less.

Circle number (38) on reply card.

(39) WATER TRUCK

A new low-bed water truck said to be capable of carrying extra large bulk loads is announced by Davey Compressor Company. Known as Model FT-50 flat-top water truck, it employs a large capacity, flat water tank, the top of which serves as the bed of the truck. Tank is constructed of heavy-gauge steel with the floor section covered with safety-plate. According to the manufacturer, one of the truck's outstanding features is its vacuum-lift system of tank filling.

Circle number (39) on reply card.

(40) PIPE DETECTOR

A battery test switch for the instantaneous testing of both transmitter and receiver batteries is included in the model "505" pipe detectors. The Detection Corporation, manufacturers, states that the operator can have assurance of maximum battery function while detecting, tracing, and estimating the depth of buried pipe.

Circle number (40) on reply card.

(41) WELDING FITTING

A welding fitting for use on low pressure transmission and distribution lines in the gas, water, and refining industries has been announced by George F. Stowell. Made from schedule 40 seamless steel tubing, these fittings are precision-cut by machine into sections, trimmed with standard bevels and ready for strong V-welding. Fittings are said to simplify field installation and turning problems by eliminating complicated layouts and time-consuming hand-mitering.

Circle number (41) on reply card.

(42) MECHANICAL SEAL

A rotary mechanical seal designed to retain process fluids under high pressures is a development of the Durametallic Corporation of Kalamazoo, Michigan. According to the manufacturer, this particular type of mechanical seal is designed for pressures from 50 to 600 psi, temperatures from minus 80 F to plus 400 F.

Circle number (42) on reply card.

(43) ENGINE CARRIERS

Baldwin-Lima-Hamilton Corporation, construction equipment division, has consolidated its manufacturing program to include the production of rubber-tired, one and two engine carriers for machines in its power shovel, crane, and dragline line.

Circle number (43) on reply card.

(44) CUTTER WHEEL

Erie Tool Works has announced a Pipemaster cutter wheel merchandiser, the first pre-packaged pipe tool part. Pipemaster card is designed to increase the unit sale of wheels to three, to protect the cutting edge, and to provide a place in tool kits for hard-to-find cutter wheels.

Circle number (44) on reply card.

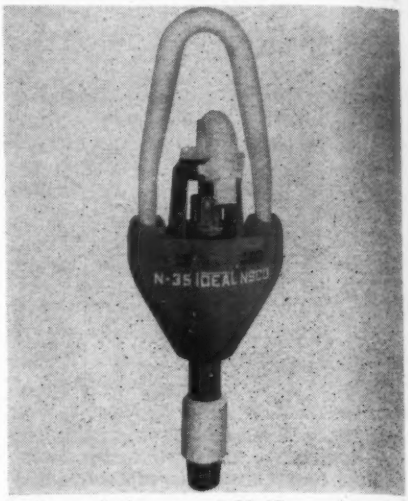
(45) SAFETY RELIEF VALVES

A safety relief valve incorporating a new seating principle using a soft seat made of Teflon is being produced by Anderson Greenwood and Company. Valve is said to have ability to seal itself absolutely after relieving which allows it to relieve or to be check popped many times.

Circle number (45) on reply card.

(46) IDEAL SWIVEL

Ideal N-35 swivel, for the 3000 to 5000 ft depth range, has been announced by The National Supply Company. Swivel is similar in general design to the other N series swivels. Features of the series include a low center of gravity, streamlined



body, and the use of Uniflex wash pipe packing box assembly. The N-35 has a comparative dead-load rating of 150 tons and an overall height of 6 ft 5¾ in.

Circle number (46) on reply card.

(47) VALVES

A line of quantity-control valves said to eliminate the severe hydraulic shock accompanying rapid cut-off of large-volume flows has been introduced by Rockwell Manufacturing Company. Valves, available in 6, 4, 3, and 2-in. sizes, are designed to be used in conjunction with a Rockwell developed multi-stage register latching device on Rotocycle meters.

Circle number (47) on reply card.

(48) PLASTIC SHEETING

Formable, reinforced plastic sheeting ready for use in mass production—a moldable, high-strength, uniform-quality glass-reinforced plastic sheeting engineered for structural jobs, has been announced by Minnesota Mining and Manufacturing Company. The material—sold as Scotchply brand reinforced plastic—is a glass-in-plastic laminate.

Circle number (48) on reply card.

(49) CONTROL STATION

Well Controls Inc. has anonunced a fully packaged control station designed specifically for hydraulic oil well pumping installations. It is designed to simplify the operations of starting, shutting-in, controlling pump speeds, maintaining manifold pressure, metering of individual wells to check pump efficiencies, as well as running soluble plugs to remove paraffin deposits in lines.

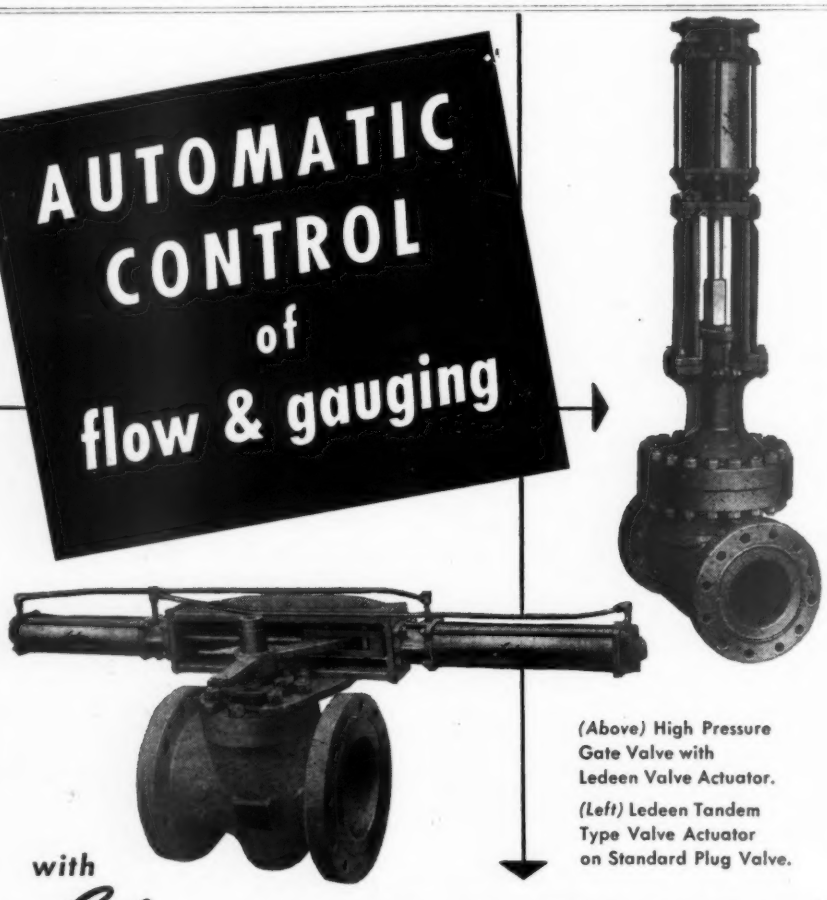
Circle number (49) on reply card.

(50) RADIO SPEAKER

In order to improve intelligibility of messages, Motorola is now shipping as a standard accessory with mobile two-way radio units a new inverted cone speaker whose cone area is said to be as much as 43 per cent greater than that of speakers found in most present day mobile radios. Advantages of speaker said to be especially apparent in fringe reception areas and where ambient audible noise levels are high.

Circle number (50) on reply card.

AUTOMATIC CONTROL of flow & gauging



(Above) High Pressure Gate Valve with Ledeen Valve Actuator.

(Left) Ledeen Tandem Type Valve Actuator on Standard Plug Valve.

with Ledeen VALVE ACTUATORS

★ Simple, Rugged Construction.
★ Few Moving Parts.
★ Easily Installed.
★ Prompt Delivery.

These actuators are for the automatic operation of gate, diaphragm, plug and other line valves, and are pneumatically or hydraulically operated for direct or remote control. Designed as package units, they are mounted directly on the valves without need of special manifolds or outside supports. They are easily, quickly and rigidly installed on new valves or on valves in service.

Ledeen Valve Actuators provide positive operation, permit automatic processing, safety installations, multiple central control ,and require a minimum of maintenance. WRITE FOR BULLETIN 3000.

VALVES • CYLINDERS
VALVE ACTUATORS
AIR HYDRAULIC
PUMPS & BOOSTERS

Ledeen Mfg. Co.
1608 SAN PEDRO
LOS ANGELES 15, CALIFORNIA

He helps teachers in 54,000 classrooms

Radio was barely out of the earphone stage 26 years ago when a new program was beamed from a San Francisco studio. It featured a string trio and was based on the idea that good music, when clearly understood, could entertain and teach, too. Actually, only 72 Western schools had radio sets then, but with that performance the Standard School Broadcast was "on the air."

Today, when Conductor Carmen Dragon lifts his baton, it's "time for the Standard School Broadcast" in over 54,000 classrooms through the West, Alaska and Hawaii. Counting children, teachers and home listeners, the program reaches a weekly audience of nearly 1½ million. That string trio has grown to a symphonic orchestra with a dramatic cast, choral group and guest vocal and instrumental artists. Selections range the musical alphabet from symphony to jazz. Each year's course follows a carefully planned outline published in a manual supplied to teachers by Standard to serve as a guide in blending music-enjoyment with subjects like art, literature, social studies. Now in its 27th year, the Standard School Broadcast is radio's oldest education program, heard today over more than 100 stations. Its goal is to help Western children gain an absorbing new interest in the world's good music, and —through music—a broader knowledge and understanding of the world around them.

Listen to the Standard School Broadcast every Thursday. Check your newspaper radio log for the time and station.

STANDARD OIL COMPANY OF CALIFORNIA

75 years of planning ahead to serve you better

NEW oil and gas Literature

- Brochures
- Bulletins
- Catalogs

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

(51) PLUG VALVES

ACF Industries, Inc., has released Catalog No. 5 on lubricated plug valves. This covers a variety of services for gasoline, oil, water, air, gas, acids, caustic solutions, chemicals, and other fluids.

Circle number (51) on reply card.

(52) PUMPS

A bulletin on self-priming centrifugal pumps issued by Worthington Corporation explains graphically the specifications, applications, and sizes of various types. Bulletin presents information on component parts, characteristics, ranges of application, and a comprehensive chart of the pump models listing their dimensions in inches.

Circle number (52) on reply card.

(53) OPERATING TIPS

Johns-Manville has issued a new edition of "Good Operating Practices," an illustrated 12-page brochure containing 101 suggestions for maintaining plant buildings and equipment. It contains the latest recommendations for getting the best service out of insulations, packings, refractory products, roofings, and friction materials.

Circle number (53) on reply card.

(54) EMPLOYMENT PREDICTION

A 32-page illustrated booklet entitled "The Story of Employment Opportunities" has been published by the Du Pont Company. Booklet, which calls for continued research, predicts that America's industrial system, if allowed to progress unhampered, can provide a quarter again as many jobs by 1975 as it does now.

Circle number (54) on reply card.

(55) DRILLING ENGINES

National Superior G-825 gas-drilling engines are described in an illustrated 8-page bulletin, No. 427, released by The National Supply Company. Ratings are 535 bhp for the 6-cylinder engine and 705 bhp for the 8-cylinder engine.

Circle number (55) on reply card.

(56) METAL GRATINGS

Penn Metal Company, Inc., has issued a folder describing its gratings of expanded steel plate. Included are tables of sizes, weights, and dimensions. Deflection tables give the load in pounds for various spans. Descriptions and illustrations of the different meshes are included.

Circle number (56) on reply card.

(57) ENGINE-GENERATOR SETS

An 8-page bulletin on "custom built" engine-generator sets is available from Le Roi division, Westinghouse Air Brakes Company. It describes and illustrates 7 engine models from 60 to 675 hp with generators capable of producing from 50 to 350 kw.

Circle number (57) on reply card.

(58) ALLIS-CHALMERS TOUR

Allis-Chalmers Manufacturing Company has published a 32-page booklet as a guide to its West Allis Works. Booklet, which gives a pictorial tour, is given to some 15,000 visitors a year.

Circle number (58) on reply card.

(59) DEWPOINT MEASUREMENT

Instrumentation data sheet 10.5-1a describes Surface Combustion Corporation's dewpoint recorder including details about the multiple source type which automatically records dewpoints from 6 different sources in rapid succession. Recorder is equipped with Brown ElectroniK recording instrument, product of Minneapolis-Honeywell.

Circle number (59) on reply card.

(60) TEL-O-SET INSTRUMENTS

Bulletin 7201 describes Minneapolis-Honeywell Regulator Company's quick-connect Tel-O-Set miniature recorder and controller. A description of the instruments and their operation is included, and specifications are given.

Circle number (60) on reply card.

(61) LIGHT MEASURING UNIT

Process control through quantitative light measurements or color comparison is described in Minneapolis-Honeywell Regulator Company's data sheet 10.10-5. This 4-page bulletin gives technical details and specifications of the Colorede computing flicker photometer with Brown ElectroniK instrumentation.

Circle number (61) on reply card.

(62) TURBINE PUMPS

"Turbine Pumps for Industry," an eight-page bulletin (No. 735-1) that describes and illustrates vertical turbine pumps manufactured by the A. O. Smith Corporation has been released. Bulletin shows characteristic curves and gives a detailed description of principal components.

Circle number (62) on reply card.

(63) TANK HEATERS

Drayer-Hanson, Inc., has published a four-page bulletin, No. 3006, on its Calfin bayonet tank heaters. Series BH and BW are shown in photographs and diagrams. Bulletin contains a table that gives surfaces, weights, and lengths.

Circle number (63) on reply card.

(64) HYDROPADS

Cook Electric Company, Magnilastic division, has issued a bulletin called Magnilastic Newsletter Vol. 2, No. 20 illustrating and describing pressurized hydropads. Besides specifications on many standard models, bulletin includes basic data in the form of tables, formulae, and charts essential to the proper understanding of the application of Hydropad principles to actual surge conditions.

Circle number (64) on reply card.

(65) STORAGE TANKS

Bulletin 916 has been released by The Pfaudler Company to describe Utilitanks, a line of vertical steel storage tanks in capacities from 1000 to 5000 gal. Tanks are built of carbon steel glassed both inside and out and are advised for storage of neutral products where non-contamination, ease of cleaning, and non-adhesion are of paramount importance.

Circle number (65) on reply card.

(66) TIPS ON PISTONS

The National Supply Company has made available a tip sheet on pistons. Illustrated sheet advocates renewing leaky pistons to prevent slush pump liner washouts.

Circle number (66) on reply card.

(67) "E"-GUN

Lane-Wells Company has issued a two-page news bulletin on performances of its "E"-Gun. Examples of the gun's use in various Texas and Louisiana fields, taken from Lane-Wells field engineers' reports, are given.

Circle number (67) on reply card.

(68) ROPE SPLICING

New Bedford Cordage Company has published a two-page sheet giving step-by-step directions on how to make an eye splice. Splicing is said to not only make a permanent junction, but also to provide a stronger connection than any knot.

Circle number (68) on reply card.

(69) MAGCOBAR PRODUCTS

Magnet Cove Barium Corporation has released a 42-page product catalog covering its drilling mud service. Catalog, illustrated in color, covers the place of mud in oil well drilling operations, basic types of drilling muds, Magcobar chemcals for drilling muds, emulsion muds, lost circulation, mud testing instruments and kits, and engineering data.

Circle number (69) on reply card.

(70) TRUCK CRANE

A new bulletin on the P&H Model 105 TC truck crane is now available from Harnischfeger Corporation. Complete details on the P&H carrier are included, along with illustrations of the 105 TC at work on a variety of jobs.

Circle number (70) on reply card.

(71) OSPHO

The Rusticide Products Company has issued a brochure which describes rust-inhibiting primer, Ospho. Ospho is not a paint—but a metal treatment. When applied to rusted surfaces it is said to change iron oxide (common rust) to an inert, hard, dark grey substance. When dry, rust action is stopped and the paint coats bond so firmly to the metal surface that moisture and oxygen cannot attack the metal.

Circle number (71) on reply card.

(72) PLUG VALVE ACTUATOR

The Pantex Manufacturing Corporation has released a two-color, eight-page illustrated bulletin that describes its new line of plug valve actuators. This line is available for the remote control of all types and sizes of wrench-operated plug valves from one inch up to eight inches. Illustrated with photographs and line drawings, bulletin gives engineering data as well as information on how the plug valve actuators are used.

Circle number (72) on reply card.

(73) WATER-CONDITIONING

Cochrane Corporation has published a four-page bulletin, No. 6210, briefly covering its water-conditioning equipment and specialties. Mentioned are demineralizers, hot process, hot lime zeolite, zeolite softeners, reactors, deaerators, dealkalizers, filters, continuous blowoff systems, hydromatic control valves, C-B condensate drainage, multiport relief valves, separators, purifiers, receiver separators, and multiport drainers.

Circle number (73) on reply card.

(74) PIPE COVERING

A folder describing aluminum pipe covering manufactured by Walex Metal Products Company is now available. Walex aluminum jacketing is a covering for insulated lines, towers, vessels, and tanks. The aluminum covering is said to be weather proof, corrosion resistant, and easily installed. Inside is coated with a specially-treated moisture resistant fiber and asphalt moisture guard to prevent moisture from affecting insulation material.

Circle number (74) on reply card.

(75) RADIO EQUIPMENT

An "engineering guidebook" to the selection and arrangement of RCA microwave radio relay equipment for point-to-point communications has been released by the engineering products division, Radio Corporation of America. The 51-page booklet "RCA Microwave Radio Relay Communications Equipment" contains photographs, cutaway drawings, floor plans, and technical data. Information covered ranges from basic RCA "building block" microwave and multiplexing equipment to typical system layouts, buildings, and antennas.

Circle number (75) on reply card.

(76) ROLLER BEARINGS

Catalog TR-854-DC, published by Rollway Bearings Company, describes the Tru-Rol line of cylindrical roller bearings. It lists Tru-Rol Bearing types, sizes, dimensions and load ratings; details their "crowned" rollers, and includes a formula for load ratings as well as a method of calculating expected bearing life.

Circle number (76) on reply card.

(77) ELECTRONIC

Custom engineering of electronic instrumentation tailored to specific industrial, scientific, and military needs is the subject of Bulletin CEC-1304 announced by Consolidated Engineering Corporation. Publication describes the role of company's newly-formed systems division. Case histories of typical instrumentation systems, applications, biophiles on key personnel, description of service facilities, and methods of planning used to solve customer problems are featured.

Circle number (77) on reply card.

(78) MICRO BLANKS

The M. N. Aitken Company, Houston, Texas, has issued a 12-page catalog giving standard dimensions and specifications for a standard series of line blinds made under the trade name of "Micro-Blanks." From catalog, a standard "Micro-Blank" can be selected to meet the requirements and ordered by code number.

Circle number (78) on reply card.

(79) FILTERS

A bulletin with installation diagrams for Hilco gas filters has been completed by The Hilliard Corporation. Bulletin F-154 includes the Hilco Hyflow Gas Filter recommendation data sheet. Diagrams of suggested installation procedures and a tabulated listing of engine horsepowers show the Hilco Filter model number to be used with the necessary number of filter cartridges.

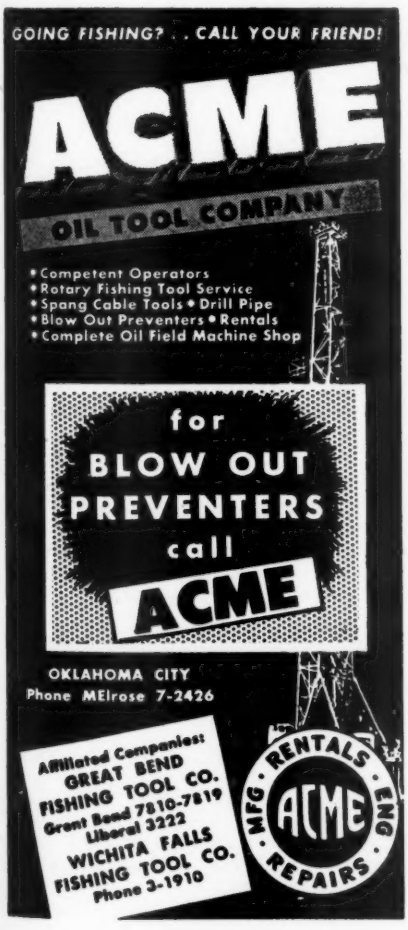
An eight page bulletin, F-132, on the use of Hilco oil filters for hydraulic systems describes the construction and operation of hydraulic systems with special emphasis on the contamination of hydraulic fluids from various causes and demonstrates how the correct filtration system eliminates such contamination.

Circle number (79) on reply card.

(80) PROPORTIONING PUMP

Hills-McCanna Company announces the release of a six-page bulletin describing the "Hills-McCannameter," a proportioning pump with no packing, unique high speed valves, and pulse free flow. Bulletin, in color, tells what the "Hills-Mccannameter" is; why it was designed; what it will do, and how it works.

Circle number (80) on reply card.

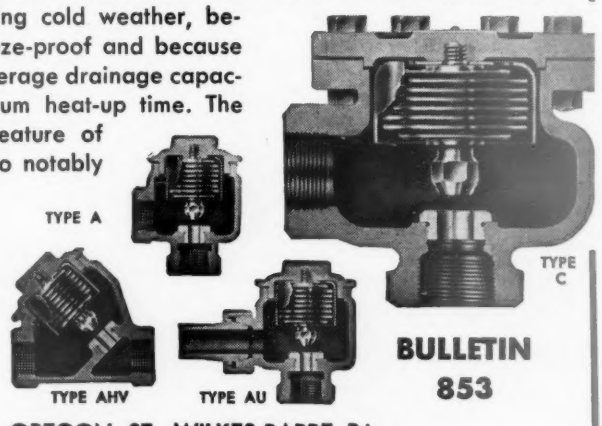


NICHOLSON MAKES

Freeze-Proof Steam Traps

for Every Plant Use

Because they drain completely when cold, these four types of Nicholson steam traps are positively freeze-proof. Can be freely installed outdoors. Universally recommended for use in lines which need not be in continuous use during cold weather, because they are freeze-proof and because their 2 to 6 times average drainage capacity results in minimum heat-up time. The non-air-binding feature of Nicholson traps also notably facilitates heat transfer in severe weather. Types for every plant use. Sizes ¼" to 2"; pressures to 300 lbs.



BULLETIN 853

217 OREGON ST., WILKES-BARRE, PA.

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

Trade Literature

(81) AIR RELEASE VALVES

The V. D. Anderson Company has published Bulletin No. 654 describing three different styles of air release valves used for venting air from (1) hot water heating systems, (2) water mains, (3) tanks in both deep and shallow well pumping systems, (4) water filters and systems in water works, and (5) for releasing air or gas from other liquid lines and tanks under pressure. Folder gives information on standard Silvertop air release valves, forged steel Silvertop for use on high pressures, and the Anderson No. "0."

Circle number (81) on reply card.

(82) BALL AND SEAT

Harbison-Fischer Manufacturing Company has published an eight-page booklet describing its DuMore ball and seat for sub-surface pumps. Valve is said to be corrosion-proof, non-magnetic, and unaffected by high temperatures.

Circle number (82) on reply card.

(83) COOLING TOWER TEST

"Test Your Tower," a 20-page booklet by The Marley Company describes a simple direct method by which the purchaser of an industrial cooling tower can test its performance. The new method is one developed by Donald R. Baker, head of Marley's Technical Services Department.

Circle number (83) on reply card.

(84) REMOTE CONTROLS

Trimount Instrument Company, which recently took over Crown Control Company, has issued a bulletin complete with graphs and specifications showing the MAT type of Hydra-Trol remote controls for controlling hydraulic valves, winches, marine engines, charging cranes, slitting machines, butterfly valves, and many other remote control uses.

Circle number (84) on reply card.

(85) CLEAN WATERS

A publication entitled "Clean Waters—And How To Get It" has been announced by the General Electric Company. The two-color, 34-page bulletin, designated GEA-6096, is designed to help civic leaders, municipal officials, and sewage treatment experts dramatize to their communities the urgency of providing proper sewage treatment and how to get it.

Circle number (85) on reply card.

(86) COOLING SYSTEMS

The dangers of scale and corrosion in cooling systems and organic contamination of cooling system water are outlined in a six-page folder issued by Hall Laboratories. It relates solutions found to cooling water problems in an oil refinery, a steel plant, and other industries.

Circle number (86) on reply card.

(87) AUTOMATIC BLOW CASES

Black, Sivalls and Bryson, Inc. announces the publication of catalog 37-15 on automatic blow cases, gas-powered high volume pumps that are completely automatic and operate on either air or gas. The unit receives liquid at low pressure and discharges it at pressures up to 2000 psi. Illustrated with cutaway drawings in color, dimensional silhouettes, and detail perspective drawings, the four-page catalog section also gives fluid capacities and solves a sample problem on how to determine power gas requirements.

Circle number (87) on reply card.

(88) CENTRIFUGAL CASTINGS

Lebanon Steel Foundry has announced publication of a new 12-page brochure on centrifugal castings. The brochure is printed in two colors on an 8½ by 11-in. page format, and contains about 30 photographs and illustrations. The brochure is divided into two main sections: One describing the "Centri-Die" casting process, in which the casting is formed on vertical axis machines using permanent molds, and the second describing the Lebanon "Centri-Spun" process, in which horizontal axis machines are used with special refractory molds.

Circle number (88) on reply card.

(89) MUD TACHOMETER

Bulletin P-7 describes Martin-Decker Corporation's pump-stroke-and-volume indicator, a gage that tells the driller the rpm's of his mud pump and the optimum mud output at each speed and for each liner size. The literature tells how this instrument can supply additional mud information necessary for today's deep drilling operations.

Circle number (89) on reply card.

(90) PRESSURE TRANSMITTER

The Swartwout Company has announced a bulletin on the flush diaphragm pressure transmitter. The two-page bulletin describes the Type P3T transmitter in detail and gives data on principles of operation.

Circle number (90) on reply card.

(91) COLLOIDAIR SYSTEMS

An eight-page catalog, "Colloidair Systems for Recovery of Suspended Materials for Waste Water Treatment," has been published by Bulkley, Dunton Processes, Inc. Catalog features data on the efficiency of the Colloidair process, flow sheets of typical installations, description of operating principles, and an analysis by types of industries of various applications for Colloidair systems.

Circle number (91) on reply card.

(92) HYDRAULIC SURGE

Cook Electric Company has issued a manual on Analysis and Control of Hydraulic Surge. The manual is illustrated with drawings, plots, nomographs, and tabular material for surge analysis of most piping systems. Fields covered are water hammer, surge-suppressing devices, surge control with pneumatic suppressors, pulsation control and resonance, accumulators, and thermal expansion compensation.

Circle number (92) on reply card.

(93) PIPE LINE PROBLEMS

Bulletin PL-1, published by Minneapolis-Honeywell Regulator Company, discusses the problems involved in transporting liquid petroleum products through pipe lines. First in a series, the bulletin describes in general terms, a typical pipe line system, the variables to be measured, and some of the problems of pipe line control.

Circle number (93) on reply card.

(94) CROWN COUPLINGS

The De Laval Steam Turbine Company has issued bulletin 2203 describing its line of crown couplings. Included is an illustration showing an exploded view of the coupling and a table containing data necessary to select the correct coupling for a given application.

Circle number (94) on reply card.

(95) BEARINGS

Gatke Corporation has released a 32-page brochure illustrating applications and describing the properties of moulded fabric bearings, wear plates, and other parts. Shows bearings made for grease or oil lubricated, water lubricated, unlubricated and acid resistant services—journal sizes to forty-eight inches diameter and larger.

Circle number (95) on reply card.

(96) RUBBER ENGINEERING

Plastic and Rubber Products Company and Parco Rubber Products Company together announce a new pictorial brochure No. 1090, Customized Rubber Engineering. It describes the types of materials, methods, measurements, and specifications used by plastic and rubber products.

Circle number (96) on reply card.

(97) TUBING HEADS

National Supply Company's Type E tubing heads in 6-in. and 8-in. sizes rated at 2000 psi are described in an illustrated 4-page bulletin, No. 424. Features are illustrated by sectional drawings.

Circle number (97) on reply card.

(98) PIPE INSULATION

MMM, Incorporated, has issued a four-page brochure on its low-temperature pipe insulation, Vapo-Wall. This illustrated folder provides a complete picture of Vapo-Wall's insulating properties, as well as recommendations on how to order and apply this pipe covering.

Circle number (98) on reply card.

(99) DUCTILE IRON

International Nickel Company has published Bulletin DI-20, on the wear properties of ductile iron. Case histories supporting National Advisory committee for Aeronautics test data show ductile iron as compared to gray iron.

Circle number (99) on reply card.

(100) HEAT EXCHANGERS

National heat exchangers of the shell and tube type, made by The National Radiator Company, for the petroleum and chemical processing industries are pictured in an 8-page bulletin. A feature of the bulletin, HT-40, is a two-page spread of engineering and drawings of many heat exchangers, and their basic component parts, to assist engineers in completing heat exchanger specification sheets.

Circle number (100) on reply card.

(101) REGULATING VALVE

Technical data covering Paul self-actuating regulating valves for product pipe line services are given in Bulletin 310, published by Paul Valve Corporation. Of the venturi-ball design, the valves are said to give quick, steady response to flow or pressure changes. Sizes from 3 to 12-in., 600 lb series, steel with high-chrome stainless hardened trim.

Circle number (101) on reply card.

(102) CASE HISTORY BOOK

C. M. Kemp Manufacturing Company has released a bulletin entitled Kemp Case Histories which features installations of Kemp industrial gas equipment at 17 major companies. This detailed report illustrates with on-the-spot photographs how companies use Kemp immersion heaters, dynamic dryers, and inert gas generators in many fields.

Circle number (102) on reply card.

TRADE PERSONALS

Richard Moses

C. J. Schleeweis

L. C. Reid

Clint Horn

The heat exchanger division of Western Supply Company, Tulsa, Oklahoma, has announced the appointment of **Richard Moses** as sales and service representative for the West Virginia area. Moses is general manager of Process Instruments and Equipment Company of Charleston.

The appointment of **Charles J. Schleeweis** as sales manager has been announced by Johnston Pump Company. Schleeweis joined Johnston in 1946. For the past six years he has been manager of the firm's export sales. He will supervise domestic and foreign sales for Johnston vertical turbine pumps.

Election of **Frank M. Hawley** as chairman of the board and of **Stanley J. Roush** as president and general manager of Morse Chain Company, a subsidiary of Borg-Warner Corporation, has been announced. Hawley previously was president and general manager of Morse Chain. Roush is also president of the Atkins Saw division of Borg-Warner, a position which he retains. Hawley has been with Morse Chain since 1916 when he started as a sales engineer.

H. H. Hippler has been appointed director of sales and service administration of Gar Wood Industries. Hippler, who has been with Gar Wood for 30 years, will be responsible for sales administration and service functions involving all corporation products. He was appointed division manager of Gar Wood's branch division in 1949 and moved to the executive offices in Wayne, Michigan.

Appointment of **Roy L. Goltz** as New York district manager for petroleum catalysts of the Davison Chemical Company division of W. R. Grace and Co., has been announced. Goltz will make his headquarters at Davison's New York office. He attended the University of Chicago and is a mechanical engineer graduate of Cornell University.

David P. Barrett has been appointed sales manager of Industrial Chemicals department. This appointment filled the vacancy created by the resignation of **N. E. Hathaway.** Barrett graduated from Gilman Country School and received a BS in chemical engineering from Princeton University in 1941. He joined Davison in 1946 as a sales trainee. He was assistant sales manager of the Industrial Chemicals department prior to his promotion.

Lewis C. Reid has been named assistant sales manager of the Industrial Chemicals Department, Davison Chemical Company Division of W. R. Grace and Company. Reid came to his new post from Wyandotte Chemicals Corporation, where he was Chicago district manager for the Michigan Alkali Division. Reid attended the University of Virginia, receiving bachelor's and master's degrees in science.

Thornhill-Craver Company, Houston, Texas, has announced the promotion of **Clint Horn** to the position of sales manager of the company's pipe line products division. For the past four years Horn has served as the Unibolt district salesman in Oklahoma City. He has been with the company six years.

Bill Pickering, formerly Shreveport, Louisiana, store manager for Bethlehem Supply Company, has joined the sales department of The Brewster Company. A veteran of more than 20 years in the oil industry, including both production and sales, Pickering will operate through southern Arkansas, Louisiana, and Mississippi from the Brewster main office in Shreveport.

Russell Herig, formerly associated with the Nye Tool Company, Chicago, Illinois, has been appointed field sales manager for Beaver Pipe Tools, Inc., Warren, Ohio. Herig has more than 21 years of technical experience in the mill supply business.

Lowell G. Moffatt has been named assistant division engineer by Halliburton Oil Well Cementing Company. Moffatt joined Halliburton in 1948 and has been district engineer at Wichita Falls and Kilgore, Texas, prior to being transferred to Dallas, Texas.

The Frank G. Hough Company, Libertyville, Illinois, has announced the appointment of **Jim Suter** as sales engineer. He will act as liaison between the sales department, Hough district representatives and other departments and will also be concerned with product improvement. His background includes four years as a Hough district representative and two years as assistant sales manager for a Hough Distributor.

Mack M. Bowen has been appointed sales representative at Corpus Christi by Rector Well Equipment Company, Inc. With the exception of two years in the Armed Services, he has been in oil industry sales and service work in the South Texas area for the past six years.

Tryad Service Corporation, Long Beach California, announces the appointment of **Jack Augsburger** as a California sales representative. He is a graduate in business administration from University of Southern California.

Ed Tracey has been named general sales manager of Walex Metal Products Company. Before coming to Walex, Tracey headed the aluminum jacketing sales division of Childers Manufacturing Company.

R. D. Ford, vice president and general manager of the Schlumberger operations in South America, has been elected a member of the Board of Directors of Societe de Prospection Electrique which operates the Schlumberger services in Europe.

E. D. Bransome, chairman of the board and president of Mack Trucks, Inc., goes over the company's new advertising program with T. J. Zeller (left), in charge of engineering and manufacturing, and Elliott G. Ewell (right), in charge of sales. Conference occurred during Boston meeting of 100 Mack representatives from Canada and New England which inaugurated a national tour of top Mack executives to review the Mack line.

Trade Personals

Clair Haas, a veteran of almost 19 years service with U.S. Steel's Oil Well Supply division, has been named manager of "Oilwell's" Williston, North Dakota, store. Haas has served as manager of "Oilwell" stores at Albany, Texas; Cut Bank, Montana; Powell, Wyoming, and Glendive, Montana.

Donald Earl Mosher has joined "Oilwell" as field representative at Bakersfield, California. He has had 16 years oil field experience.

Appointment of **George H. Fletcher** as field representative at Fort Morgan, Colorado, for "Oilwell" was announced by R. L. Armstrong, Rocky Mountain Area manager.

Louis R. Roter has been appointed field representative at Monahans, Texas, for "Oilwell." Roter was employed in February, 1948, and has held sales positions at Wichita Falls and Snyder, Texas.

Appointment of **Wayne B. Atkins** as field representative at Hobbs, New Mexico, for "Oilwell" has been announced. Atkins, who has 14 years service with the company, moved to his new post from Odessa, Texas.

Holland A. Hatcher has been appointed manager of "Oilwell's" Arkansas City, Kansas, store. **James A. Brunnemer** will succeed him as field representative at that city. Hatcher joined "Oilwell" in 1945 after three years' oil field experience. Brunnemer was employed in 1946.

Announcement has been made by C. Lee Cook Manufacturing Company, Louisville, Kentucky, of the promotion of **Clarence T. Duke,** to sales engineer. Duke's territory will include Michigan, Wisconsin, Indiana, and Kentucky. He will make his headquarters in Louisville.

E. A. Pratt

L. W. Morgan

J. D. Nicholson

R. H. Mudwilder

Brush Electronics Company has announced the appointment of **Ernest A. Pratt** as field supervisor of its oil instrumentation section. Pratt attended the Virginia Military Institute and took graduate studies at the Colorado School of Mines. Pratt, who has had ten years association with the geophysical industry, will maintain headquarters in Houston, Texas.

Alten Foundry and Machine Works, Inc., Lancaster, Ohio, has announced that **Lloyd W. Morgan** has been appointed Alten sales representative in the Gulf coast area. Morgan entered the petroleum equipment business in 1945 and has spent the entire 10 years in the Arkansas-Louisiana-Texas area with the McGriff Sales Company in Shreveport He has headquarters in Shreveport, Louisana.

Hans U. Lieberherr has been appointed director of engineering for Nordberg Manufacturing Company. **Emil Grieshaber** was named director of projects development, and **Ralph Miller** as consultant and director of supairthermal development.

Southern Engine and Pump Company has announced the appointment of **John D. Nicholson** as sales manager. He began as sales engineer with the firm in 1948. Nicholson received his engineering degree from the University of Missouri School of Mines and Metallurgy in 1942 and attended the Yale University Engineering School.

The catalyst division of National Aluminate Corporation has announced the appointment of **Robert H. Mudwilder** as a technical representative in the Midwest area. A mechanical engineering graduate of the University of Louisville, Mudwilder was previously sales engineer for the General American Transportation Company.

Bethlehem Supply Company has announced the promotion of **D. L. Ligon** to store manager and field representative at the Graham, Texas, store. Ligon, formerly field representative at Graham, has been with Bethlehem since June, 1950. He replaced **P. J. (Pat) Ryan,** who died recently after a long illness.

L. D. Harris has been promoted to field representative at the Sterling, Colorado, store. He was formerly a clerk in the Sterling store.

W. J. Overton has recently been employed as a clerk in the tubular goods section of the General Sales office in Tulsa. He will help expedite the handling of pipe and tube orders in the Tulsa Sales Office.

Jack Wyatt has been named district manager of the Detroit, Michigan, area for Electro Dynamic division of General Dynamics Corporation. A graduate of Michigan State University, he has had five years of experience in electric motor power transmission equipment and related fields.

Dr. Charles H. Leigh, recently of Brookhaven National Laboratory, has joined the Catalysis section of The M. W. Kellogg Company's research laboratory at Jersey City, New Jersey.

Jim Callery has been assigned to Argentina in connection with Kellogg's project being constructed in that country.

The appointment of **Ralph W. Gundersen** as chief industrial engineer of the American Hoist and Derrick Company, St. Paul, Minnesota, has been announced. Gundersen was graduated from Northwestern University and has been engaged in industrial engineering since 1934. He joined American Hoist in 1951.

The Hydreco division of the New York Air Brake Company, Cleveland, Ohio, has announced the appointment of **Ray J. Thomas** as manager of its sales order department. Thomas has been with Hydreco since 1945 and has held positions in the engineering, service and sales departments.

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▸ New assistant managers have been assigned to the eastern and gulf coast regions of the Du Pont Company's petroleum chemicals division. **Wesley T. Dorsheimer** has been promoted to assistant manager of the eastern region. He replaced **Barry V. Cornwall,** who has been named assistant manager of the Gulf coast region. Cornwall fills the post formerly held by **Robert F. Harwick,** who has been named assistant sales development manager of the rubber chemicals division.

▸ Announcement is made of the election of **Max A. Minnig** as executive vice president of Witco Chemical Company, New York, New York. Joining Witco's natural gas division in 1946, Minnig successively has been national sales manager for Rubber Chemicals, director of sales, and vice president.

▸ **A. F. Milbrath,** chief engineer and vice president of Wisconsin Motor Corporation, Milwaukee, Wisconsin, has retired from active duty after 45 years of continuous service. A leading designer of internal combustion engines, Milbrath designed the T-head engine that powered Stutz Bearcat cars, also a marine engine which became standard with the Coast Guard. He designed his first air-cooled engine in 1930. He has been a member of the Society of Automotive Engineers since 1910.

▸ Dowell Incorporated has promoted **D. E. "Pat" Ramsey** to manager of operations in the company's general office in Tulsa, Oklahoma. Ramsey has been district manager of Dowell's West Texas operations with headquarters at Midland, Texas. He will assume his new position January 1, 1955. **Edward F. Kelly,** formerly Dowell district area manager for West Texas, has succeeded Ramsey as district manager.

▸ **J. Frederic Wiese,** vice president of Lukens Steel Company, has received a certificate of Honorary Life Membership in the National Security Industrial Association. He is the only one who is not a member of the Armed Services to receive the award this year. Wiese has been a member of the board of trustees of the Association since its inception in 1944 and has also served as chairman of the board and as president.

▸ Precision Thermometer and Instrument Company, Philadelphia, Pennsylvania, has announced the appointment of **Harry F. Ogden, Jr.** Ogden, a chemical engineering graduate of Villanova University, will supervise national and international distribution. Precision's Cleary, a former physics instructor at Bucknell University, will supervise research and development, and plant, sales, and service engineering for the company's production.

▸ **Charles E. Seelig,** manager of land turbine sales of the General Electrical Company's small turbine and supercharger department, took part in a discussion on high speed turbine design problems and applications at the Ninth Annual Petroleum Mechanical Engineering Conference in Los Angeles, California.

▸ Promotion of **Norman Lieblich** to the post of vice president of Kieley and Mueller, Inc., Middletown, New York, has been announced. Lieblich was general sales manager, and previously had served as chief applications engineer.

▸ The appointment of **Edgar K. Shutz** and **Robert Allan** as sales representatives and the transfer of **Thomas E. Goodyear** was announced recently by Wolverine Tube, divsion of Calumet and Hecla, Inc. Formerly a sales representative for the Sherwin-Williams Company, Schutz will be located at Wolverine's Chicago, Illinois, office. Allan was previously regional sales manager for Briggs Manufacturing Company. Goodyear has opened an office in Moline, Illinois.

S. Land

▸ **Stuart Land** has been named controller of C-R-C Engineering Company of Houston, Texas. He will also serve as controller of C-R-C Engineering of Canada, Ltd. Land has been serving as assistant controller of C-R-C Engineering for the past 15 months. He was formerly associated with Crown Central Petroleum Corporation in Houston and Magnolia Petroleum Company and Sun Pipe Line Company in Beaumont, Texas. He is a native of Beaumont and was graduated from the University of Texas.

▸ **Charles Gardner,** who has been associated with the paint industry for 18 years as chemist and plant manager, has been appointed sales manager, drier division, of Witco Chemical Company, New York. Until recently he was eastern sales manager, Technical Sales and Service, of Advance Solvents and Chemical Corp., and Technical Director, Advance International, Ltd.

▸ **F. A. Henry,** formerly assistant to the general manager of A. O. Smith Corporation, Milwaukee, Wisconsin, has been appointed general manager of the corporation's Pacific coast works at Los Angeles, California. He succeeds **A. W. Shuman,** who has resigned. Henry joined A. O. Smith in August, 1953.

F. L. Mill

▸ **Frank L. Mill** of Tulsa, Oklahoma, has been appointed representative in the Mid-Continent area for Murray Rubber Company of Houston, Texas. For the past four years he has worked in the mid-continent area of Oklahoma, Kansas, and parts of Texas and Missouri.

▸ **Lawrence E. MacDonald** has been appointed general sales manager for Bucyrus-Erie Company, South Milwaukee, Wisconsin. MacDonald is responsible for domestic sales. A graduate of the University of Chicago, he has served the excavator manufacturer for over 28 years. Since 1949 he has been sales manager, excavator distributors.

▸ The Continental Supply Company has announced the appointment of **Raleigh Hortenstine, Jr.,** as vice president in charge of Gulf Coast operations and **Richard A. Gentry** as manager of the Gulf Coast division. Hortenstine assumes the duties of the late **N. A. Endicott,** while Gentry takes over the division manager position formerly held by Hortenstine.

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NEW, sturdier body design with sheet metal flanged and overlapped for extra strength . . . center mounted to relieve road strain and for even greater sturdiness.

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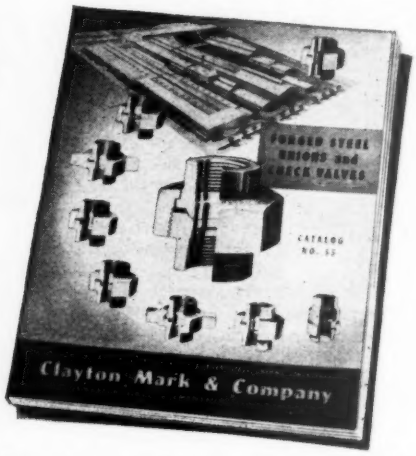

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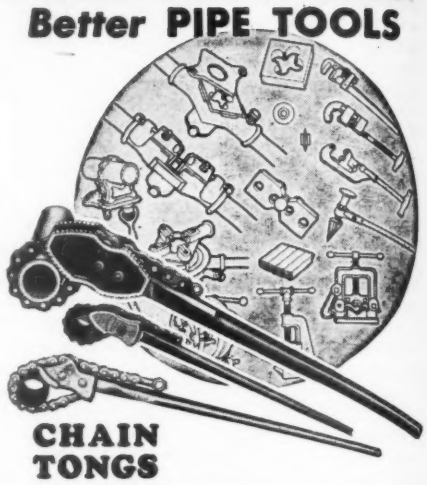

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Paul A. Manor of Columbus, Ohio, a design engineer with Surface Combustion Corporation at Columbus for the past ten years, has been named chief engineer of Rockwell Manufacturing Company's lubricated plug valve plant at Barberton, Ohio. He attended Ohio State University and the University of Ohio. He joined Surface Combusion in 1931 and worked at the Toledo plant for seven years.

Tube Turns, Louisville, Kentucky, has announced the reorganization of the company's sales department. Appointments were made as follows: **John E. Chumbley, Jr.,** assistant general sales manager; **Thomas H. Pike, Jr.,** merchandising manager, who supervises merchandising activities of the Louisville general sales office and has supervision of the Houston and Los Angeles plants and the Engineering Service Division; **Jack W. Green,** executive assistant; and **Charles F. Morris,** sales manager of the forgings division.

Lincoln D. Hall, assistant sales manager, administers sales policies and sales in the Tulsa, Houston and West Coast territories; **Elmer H. Dilley** is manager of the general sales office; **H. Dewey Gass, Jr.,** manager of the order service department; **Dan R. Cheyney,** assistant manager of the engineering service division; and **Jack D. Tolliver,** assistant manager of the engineering department.

William G. McDaniel, formerly a sales engineer with The Foxboro Company branch office in Houston, Texas, has been appointed manager of the company's branch in Corpus Christi, Texas. McDaniel replaced **W. A. Rock** who recently joined the firm of Schultz y Cia., S.A., Foxboro representative in Mexico.

Lukens Steel Company has announced the appointment of **Eugene M. Smith** as assistant director of research. Smith was previously with Youngstown Sheet and Tube Company, Youngstown, Ohio, where he was development engineer in the mill research and development department.

Appointment of **E. H. Bennett** to district manager of the Twin Disc Dallas, Texas, branch is announced by Twin Disc Clutch Company, Racine, Wisconsin. Bennett replaced **H. A. Davis,** who has resigned. Bennett was assistant district manager of the Dallas branch from 1945 to '47. Previous to his new appointment, he was district manager of the Twin Disc Newark branch.

R. S. Battles

R. S. "Bob" Battles has been added to the sales staff of Thornhill-Craver Company of Houston, Texas. He will serve Oklahoma and Kansas with his headquarters in Pauls Valley Oklahoma.

Battles has had wide experience in drilling and producing problems in both Oklahoma and Kansas gained while representing one of the larger supply companies in the area and serving as a supply store manager in Kansas.

Barrett division, Allied Chemical and Dye Corporation, has appointed **James E. Sayre** as manager of its marketing research department. A Barrett economist since 1939, Sayre has had economic studies published in various chemical journals on coal chemicals.

Franklin Supply Company has announced the opening of supply stores at Ratliff City, Oklahoma, and Abilene, Texas, and transfer of personnel. **Frank Kenefake,** formerly field salesman at Odessa, Texas, has been transferred to Abilene in the same capacity. **Joseph Turek,** formerly manager of the store at Mt. Pleasant, Michigan, has been appointed manager at Abilene. **Bob Spellman** has been transferred as field salesman from Oklahoma City to Ratliff City and **Jack Carroll** has been appointed store manager. **Jean McIntyre** replaces Carroll as store manager at Oklahoma City. **Vernon Neal** has been promoted to store manager at Grayville, Illinois. **Jack Orr** has been transferred from Chicago to New York as manager, eastern division.

W. J. McWilliams has been named assistant to the president and secretary of Republic Supply Company. McWilliams will handle the corporate records of the company and act as personnel director and manager of office service, serving in the company headquarters at Oklahoma City, Oklahoma. He was employed previously by the U. S. Government, serving in the field of International Economic Affairs, office of the Assistant Secretary of State for Economic Affairs.

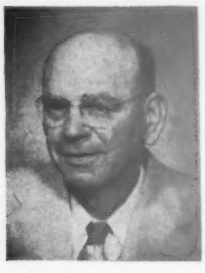
Appointment of **G. Allen Lovell** as assistant general manager of the mechanical goods division, United States Rubber Company, has been announced. He rereplaced **Herbert G. Kieswetter,** now executive assistant to the general manager of the company's international division, who will supervise activities of the international division in Great Britain and Europe. Lovell will have responsibility for supervising production and research as well as sales operations in the mechanical goods division.

A reorganization of the top executive staff of Morse Chain Company, a Borg-Warner Corporation subsidiary operating plants in Ithaca, N.Y., and Detroit, has been announced. **Louis Paul Smith,** who has been vice president and Ithaca plant manager, has been named vice president of manufacturing operations of the entire company. **M. F. Bailliere**, formerly controller and assistant secretary at Ithaca, has been made responsible for all finances of the company. **Norman C. Bremer,** previously chief engineer at Ithaca, takes on the additional duties of chief engineer at the Detroit plant. **James V. Davis** adds the Detroit plant to his responsibilities as industrial relations manager.

The appointment of **James C. Gray** as vice president, operations, coal of United States Steel Corporation, has been announced. Gray was previously with U.S. Steel's Tennessee coal and iron division, where he has been manager of manufacturing operations. In his new position he heads the company's coal mining activities in Pennsylvania, West Virginia, and Kentucky. He succeeded **Karl L. Konnerth.**

Appointment of **B. Y. Auger** as general supervisor of the Scotchply Plastic Development Group of 3M's tape division has been announced by Minnesota Mining and Manufacturing Company, St. Paul, Minnesota. Auger will be responsible for all functions of the group with respect to product research, experimental production, and market development of 3M's Scotchply plastic. The group's laboratory will be maintained in St. Paul.

R. F. Benda



R. S. Amend

Robert F. Benda has been appointed district manager in the Gulf Coast area for Willis Oil Tool Company of Long Beach, California. Benda is in charge of sales and service and maintains offices and factory warehouse stocks of the Willis line. He is a graduate engineer and for the past 11 years has been engaged in oil industry equipment engineering sales work in the southwest.

R. S. Amend has been transferred from the factory at Long Beach, California, to the Houston branch as assistant to Benda. Amend will specialize in field engineering application and service from the office at Houston.

E. C. "Gene" McCann has been named Louisiana-Mississippi sales engineer for Edward Valves, Inc., East Chicago, Indiana, subsidiary of Rockwell Manufacturing Company. McCann formerly worked for Houston Oilfield Material Company.

Marlow Pumps division of Bell and Gossett Company has announced that **F. R. Paris** has been appointed assistant sales manager. In addition to assisting with sales policy, Paris will directly supervise all Marlow division district engineers west of the Mississippi. He has been with the company as a district engineer for the past five years.

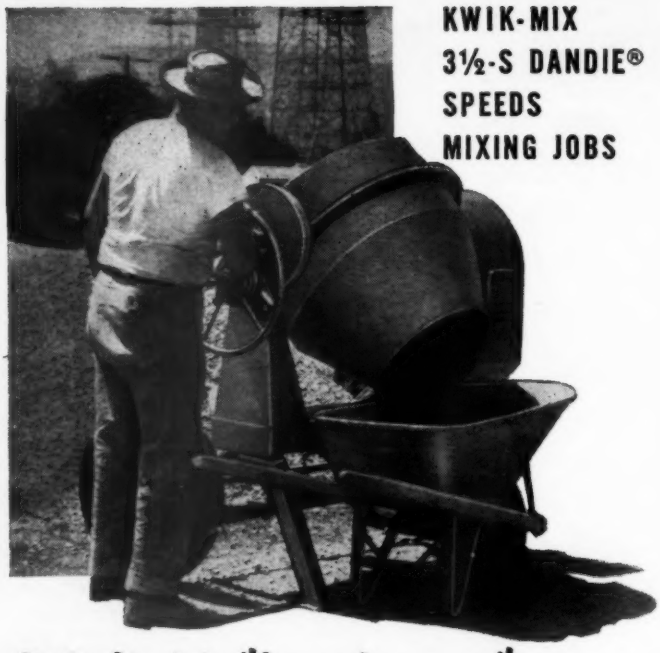
Fluid Packed Pump Company announces the promotion of **Bill Lohman** to Oklahoma district manager. In his new position Lohman will headquarter at Oklahoma City and will assist **G. R. Newbolt** in supervising Oilmaster pump sales and service. Lohman joined Fluid Packed Pump Company's sales force at Odessa, in 1947.

Layne and Bowler Pump Company of Los Angeles, California, has engaged **James W. L. Stone** to head industrial sales. Stone has been continuously active in the pump industry for 18 years. Past connections include manufacturers and distributors.

Bethlehem Supply Company announces the promotion of **H. D. Garbett** to store manager of the Winnsboro, Texas, store. Garbett has been employed by Bethlehem since 1939 and most recently was special representative in the Shreveport, Louisiana, area. **H. B. Carroll, Jr.,** will be the field representative at the Winnsboro store.

Company also announces the promotion of **W. Q. Mitchell** to store manager of the Shreveport, Louisiana, store. Mitchell has been with Bethlehem for 24 years. He was store manager at Winnsboro for five years, prior to being transferred to Shreveport in 1953 as assistant store manager of the Shreveport store.

W. C. Sheehan has been promoted to field representative in the Kermit, Texas, store. Sheehan formerly was a floorman at Sundown, Texas, and more recently a clerk in the Kermit store.



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3½-S DANDIE®
SPEEDS
MIXING JOBS

Oil field "handyman"

For pouring footings, laying concrete slabs, and handling all other widely-scattered mixing jobs around refineries, yards, booster stations or drill sites, here's a portable "handyman" that does on-the-spot mixing. Kwik-Mix 3½-S Dandie produces high-quality concrete fast, at low cost, anywhere on your property.

IT'S AS PORTABLE AS A WHEELBARROW....

Balanced light weight, low center of gravity, roller-bearing wheels, and handy push-down tow-pole provide easy one-man spotting on the job . . . and give smooth, fast towing job-to-job. Low charging height is only 43 inches. Easy-tilting drum is self-locking in any discharge position. The all-welded steel drum has reinforced lip, separate ring gear, and box-section yoke for long-wearing durability. This utility-size 3½-S Dandie also has multiple V-belt drive, standard 3.4 h.p. air-cooled gas engine, antifriction bearings throughout. It's available in 3 models: end-discharge tilter (shown here), end-discharge non-tilt, and a side-discharge tilter.

See your Kwik-Mix distributor for full details, or send for bulletins on this 3½-S, or on the larger 6-S, 11-S, 16-S sizes.

mail to: KWIK-MIX COMPANY 3029 W. Concordia Milwaukee 16, Wis.

Send us bulletins on: ☐ 3½-S ☐ 6-S ☐ 11-S ☐ 16-S concrete mixers

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BOOKS ★

Oil and Petroleum Year Book, 1954, *published by Walter E. Skinner, 20 Copthall Avenue, London, E.C. 2. Pages, 678. Price, $5.00, post free abroad.*

The 1954 edition, the forty-fifth year of issue, of this reference work, was compiled by Walter E. Skinner. Complete and up-to-date particulars are given concerning 945 companies operating in all parts of the world and covering all branches of the oil industry, together with a list of names and addresses of 628 managers and engineers and the companies in the book with which they are connected.

Book contains information on the principal British, American, Canadian, and foreign companies.

The particulars of each company comprise names of directors and other officials, description of business, where operating, crude oil production, refinery runs, details of capital, dividends, and financial results.

The Buyer's Guide of Manufacturers of oilfield and refinery equipment comprises 875 headings.

General Index to Petroleum Publications of the American Institute of Mining and Metallurgical Engineers (1921-1952), *published by the Petroleum Branch, American Institute of Mining and Metallurgical Engineers, 800 Fidelity Union Building, Dallas, Texas. Pages, 150. Price: $5.00, AIME members, $3.50.*

This index covers all petroleum publications of the AIME from 1921 through 1952, and is compiled by author's names and by subject.

In addition, the names of companies and universities or colleges, as sponsoring institutions, have been indexed since 1938.

Publications indexed include Petroleum Transations, Antitrust Laws et al vs Unit Operation of Oil and Gas Pools, Petroleum Conservation, Elements of the Petroleum Industry, Journal of Petroleum Technology, from 1949-1952, Mining and Metallurgy, 1921-1948, Petroleum Technology, and special contributions and technical publications of the AIME.

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LAUGH with BARNEY

An employer was severely reprimanding a meek employee. "Mr. Jones, I understand you've been going over my head," stated the employer.

"Not that I know of, sir," ventured the meek employee.

"Isn't it true that you've been praying for a raise?" asked the employer.

Do you know how a Sultan chooses the best girl for his Harem? He lines all of them up and as they pass by, his servant throws water on them. If one sizzles, that's it.

A Texan arriving at the gate of his eternal home remarked, "I never thought heaven could be so much like Texas."

"Son," replied the gatekeeper, "this isn't heaven."

"What's the charge?" asked the judge as a married couple was presented to the court.

"This man is charged with beating his wife with an oak leaf," sand the sheriff.

"Why was he arrested for that?"

"He got the oak leaf out of the dining room table."

In these days of low-cut gowns, tight-fiting waists and sheer stockings, it takes will power for a man to look a woman in the eye.

An Easterner was being driven by a rancher over a blistering and almost barren stretch of West Texas when a large brightly-colored bird scurried across the road in front of them. The visitor had never seen a bird like that and asked what it was. "That's a bird of paradise," said the rancher.

"Pretty long way from home, isn't he?" remarked the visitor.

A Boston spinster was shocked at language two telephone repairmen used while working on some wires. She reported the incident and immediately the manager asked the men what they said.

"Me and Spike were on this job. I was up the pole and accidently let some hot lead fall on Spike—and it went down his neck. Then Spike looked up at me and said: 'Really, Harry, you must be more careful.' "

At a recent shipyard launching the woman who was to christen the boat was nervous.

Shipyard Manager: Do you have any questions, lady?

Woman: Yes, how hard do I have to hit it to knock it into the water?

Wife: Well, what excuse have you for coming in at this time of night?

Hubby: Well, my dear, I was playing golf with some friends and . . .

Wife: What? 2 a.m.?

Hubby: Sure, we were using night clubs.

He asked the secretary how she was doing in her race for matrimony and she said: "'I'm doing all right. I think I'm on the last lap now."

"Paw," said the farmer's boy, "I want to go to college and study obstetrics."

"Likely you'll be wastin' your time, son," replied the father. "Soon as you learn about it, somebody'll come along with a cure for it."

It takes hundreds of nuts to hold a car together, but it takes only one of them to scatter it all over the highway.

Female elevator operator in car alone with a marine: "Going up—going up—anybody else going up? Please, will somebody else go up?"

When the woman motorist was called upon to stop, she asked indignantly,

"What do you want with me?"

"You were traveling at forty miles an hour," answered the police officer.

"Forty miles an hour? Why, I haven't been out an hour," said the woman.

"Go ahead," said the officer, in despair.

When a true son of old Kentucky was asked why he closed his eyes when he drank his liquor straight, he explained:

"Just the sight of good likker makes my mouth water and I don't want to dilute good likker."

WISCONSIN-POWERED

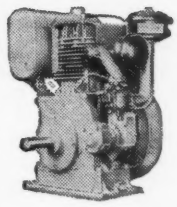
Gathering Pump Unit Weathers 11-Inch Rain Storm in Louisiana Delta Country Oil Field

Back in the Louisiana Terrebonne Parish delta country, Wisconsin-powered Gathering Pump Units take a terrific beating from the elements.

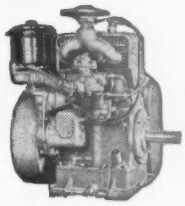
Not long ago two Harley Sales Company service engineers, while making their rounds in this oil field, had occasion to check the platform-mounted installation shown above, on which a Wisconsin Model VG4D Heavy-Duty Air-Cooled Engine was operating with the canopy housing removed, leaving the engine fully exposed to the weather.

Shortly after starting the engine a 70 m.p.h. gale broke, dumping 11 inches of rain while the Wisconsin-powered gathering pump began the transfer of 1000 bbls. of oil. The next morning the tanks were empty and the engine no worse for the ordeal . . . again demonstrating the all-weather dependability of Wisconsin Air-Cooled Engines.

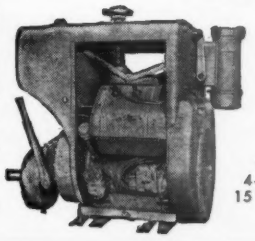
You can't do better than to specify "Wisconsin Engine Power" for your oil field utility units.



4-cycle single cylinder 3 to 9 hp.



2-cylinder models 7 to 15 hp.



V-type 4-cylinder 15 to 36 hp.

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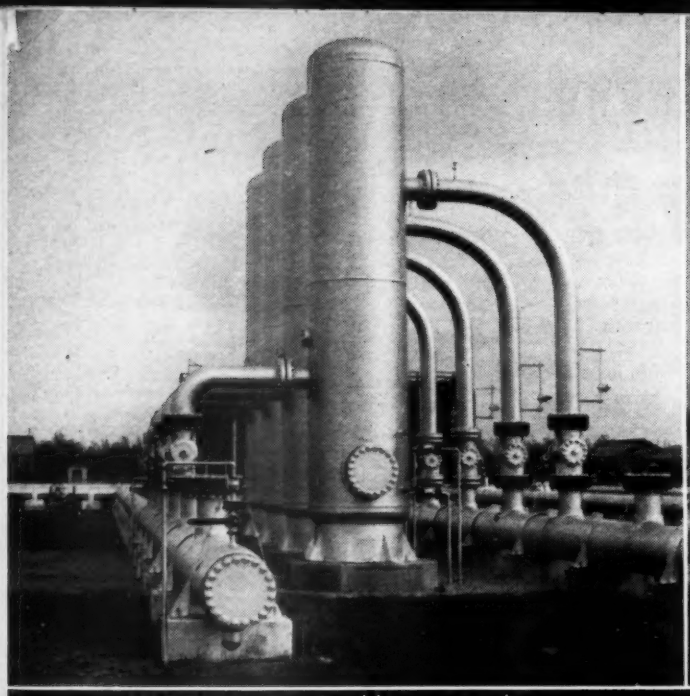
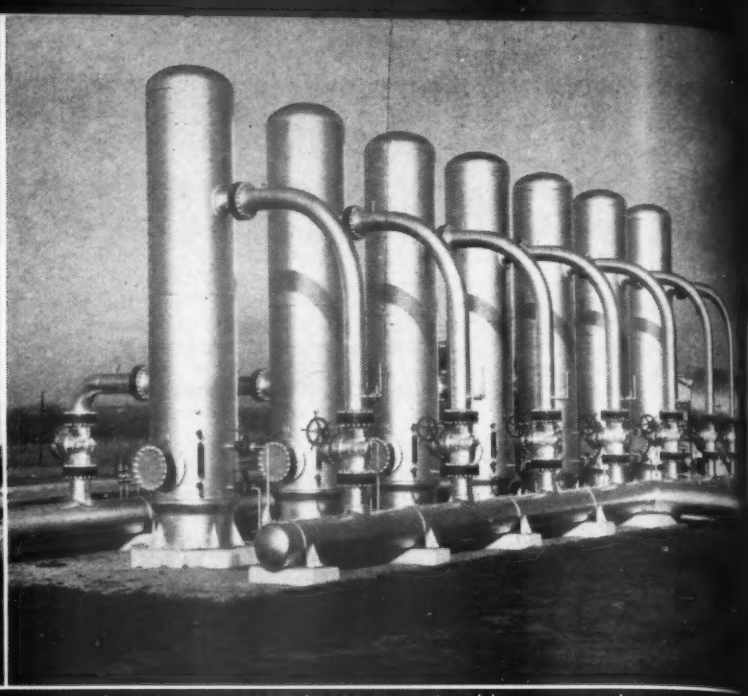
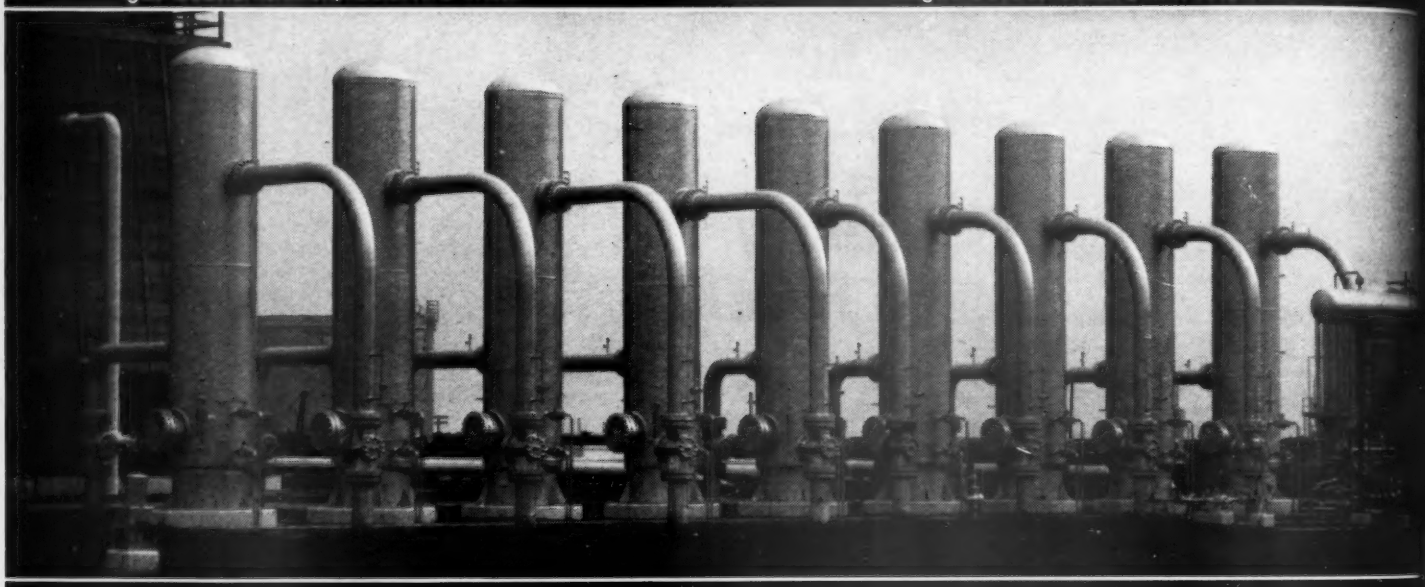


NATIONAL Gas Scrubbers, main line gas booster station, Batesville Miss.



NATIONAL Gas Scrubbers, main line gas booster station, Monroe, La.



NATIONAL Gas Scrubbers, main line gas booster station, Banquitte, Texas

NATIONAL WET-TYPE SCRUBBERS

54" O.D. x 20' — 750 PSI MAX. WP.
90 MM CU. FT./DAY. 12" INLETS AND OUTLETS

The service required of Wet-Type Scrubbers! Pipe line dust and other foreign materials are removed ahead of compressors at each pressure boosting station. This is done best by passing the gas through a special oil bath in a National Wet-Type Scrubber, then removing the liquid particles from the gas stream when passing through the National Gas Scrubbing element in the top part of the Scrubber.

National Vertical and Horizontal Gas Scrubbers are available in a wide range of sizes, working pressures and capacities to fit the needs of gas producers and carriers.

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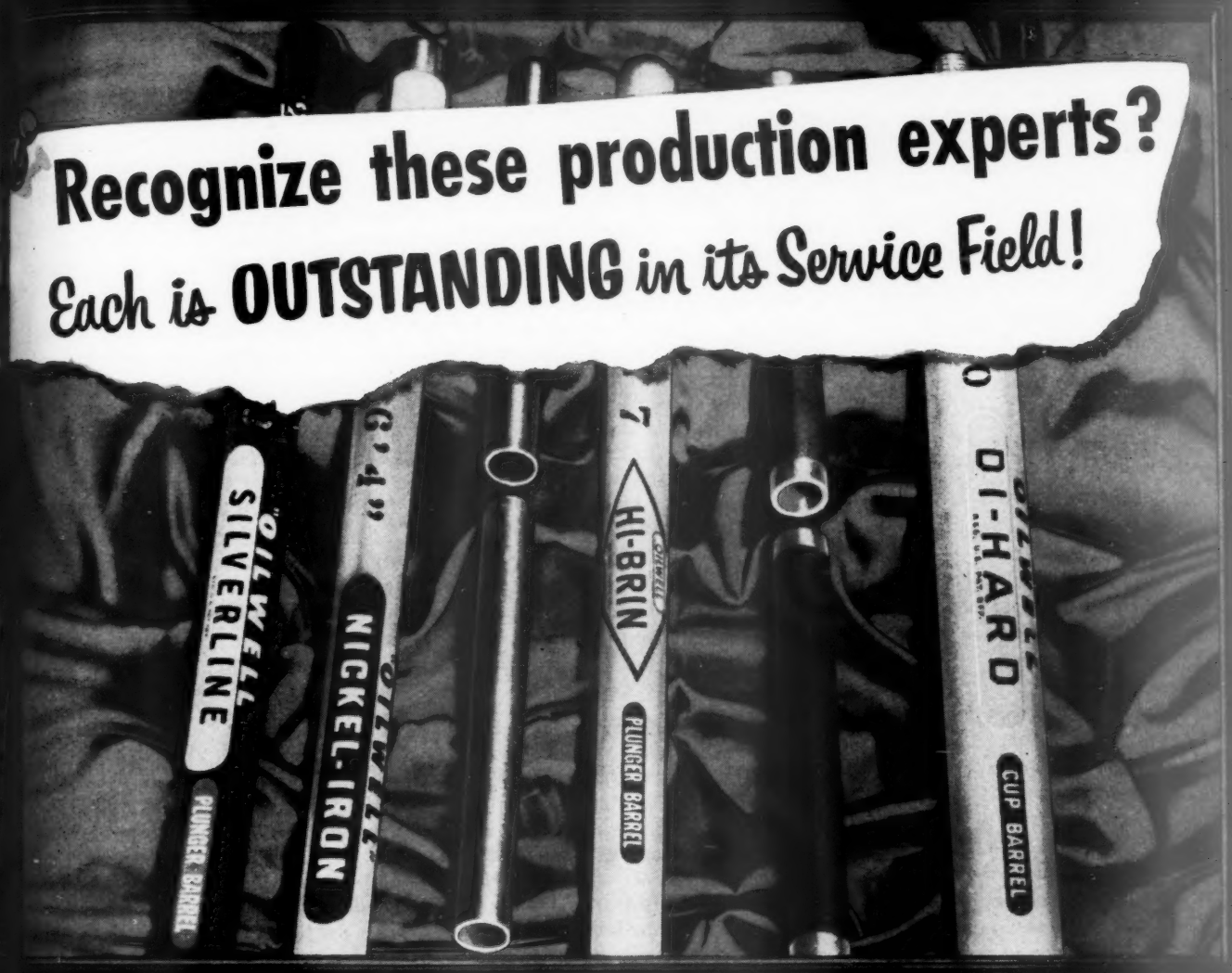
Recognize these production experts?

Each is OUTSTANDING in its Service Field!



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SILVERLINE . . . is an inexpensive, accurately-honed, cold-drawn, seamless-steel barrel for wells to 4,000 feet; in which loads are light, and corrosion and abrasion are not serious problems.

NICKEL-IRON . . . is an inexpensive barrel for wells to 5,000 feet where medium corrosion and medium abrasion exist. Barrels are drilled and honed from solid castings of nickel-alloy iron.

SPUN CHROMOLOY HARD SECTIONAL LINERS . . . are also suited for medium corrosive and abrasive conditions. Assembled in tough jackets of desired length, they are able to withstand the pressures encountered in wells to 7,500 feet.

HI-BRIN . . . is "Oilwell's" new special-alloy pump barrel for all depth wells where abrasion and high hydrogen sulphide corrosion are found. Our exclusive Nitrocycle bore-hardening process results in extreme hardness and permits exceptionally accurate bores over long lengths.

DI-HARD . . . in SECTIONAL LINER and FULL BARREL construction is unexcelled for deep well pumping. This material resists extreme carbon dioxide as well as hydrogen sulphide corrosion. Its low coefficient of friction resists abrasion and permits the use of metal-to-metal DI-HARD plungers which maintain uniform clearances under temperature changes, and minimize electrolytic corrosive action. Exclusive locking rings on DI-HARD sectional liners permit jacketed assemblies in pump lengths to 30 feet and over.

PROVE IT YOURSELF! You can get more barrels of oil with fewer pulling jobs when you equip each of your wells with . . . THE RIGHT "OILWELL" SUBSURFACE PUMP.

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LETTERS

Blowout Preventers

Would it be possible for us to receive 15 to 20 copies of the article entitled "Blowout Preventers" by Marvin R. Jones, on pages B-97 through B-104 of the January, 1955, issue of *The Petroleum Engineer?*

This is one of the best articles on this particular equipment that has ever come to our notice and will prove of considerable value to our Engineering Department as well as sales representatives handling this class of equipment. It has occurred to us that you may make a practice of preparing reprints of articles of this kind, for which we are perfectly willing to pay the cost.

May we hear from you soon in regard to this matter?

G. W. Rheinfrank

National Supply Company
Export Division
New York

Note: All credit for this particular article in the Drilling Fundamentals series is due Mr. Jones, who has worked diligently in the preparation of this work which began nearly one year ago. Since its inception, constant inquiry has been made with the various manufacturers involved, with operators, and with our staff. Correspondence has become voluminous. We trust that many others in the industry will find this, and the other articles in this series, of great practical value. Reprints are being forwarded.

Gas Calculations

With a great deal of interest I am studying the first of 3 sections of the article "Calculation of Flow and Storage of Natural Gas in Pipe," R. G. Nisle and Fred H. Poettmann, that appeared in the January, 1955, issue of *The Petroleum Engineer*, OIL AND GAS PIPELINING EDITION. I was recently asked to assist in the design of a long pipe line for gas to be installed in a foreign country, and the possession of all three parts of this article would be of great value to me. . . . I am wondering whether such reprints have been made.

To be of maximum value to me I need the articles before the 3rd part comes out in *The Petroleum Engineer*, presumably in March.

On page D-16, first section, the statement is made that the values of integral functions can be obtained from Table 1, Appendix 3. This table is not given. I assume it will be given in the 2nd or 3rd part.

As always, *The Petroleum Engineer* offers articles of much interest and great value, and I congratulate you on your choice of articles and their editorial treatment.

Fritz Karge

Corona Del Mar
California

Note: Tables 1 and 2 to accompany the article will appear in the February and March issues. A limited number of reprints will be available after completion of the series. And many thanks for the kind comments.

Wants Drilling Fundamentals

I have been a subscriber to *The Petroleum Engineer* only since August, and I have become very interested in your serial entitled Drilling Fundamentals.

Will you kindly inform me when this serial started and how I can get hold of any missing articles?

Manuel Alfonso Foghe

Miramar, Havana
Cuba

Note: The Drilling Fundamentals series began in the June, 1954, issue. They will continue until 55 articles, encompassing the entire drilling cycle, have been published. Following this series in the magazine, the combined material will be printed in book form.

Crude Oil Characteristics

The August 1954 Management Edition of the *Petroleum Engineer* contained an article entitled "Study of Properties of Gulf Coast Crude Oils," by J. B. Stripling and R. B. Thompson. It was mentioned that this was the third of new series of articles on crude characteristics.

I found this article very interesting and would appreciate your advising the dates of publication and issues in which similar type articles have appeared.

J. J. Pope

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Note: We're glad you are interested. We published two articles in our July, 1954 issue on the subject. They are "A Crude Oil Characterization by the Bureau of Mines," by H. S. Smith and John M. Ball, on page C-12, and "Characteristics of Petroleum from Williston Basin Fields," by W. A. Wenger and W. J. Lamm, on page C-43. An extensive list of such articles are in the hopper and will appear in our pages just as rapidly as they can be prepared.